

# PROVINCE OF ONTARIO

STANDARDS DEVELOPMENT BRANCH OMOE



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## PRESENTATION TO:

**THE MICHIGAN AIR POLLUTION CONTROL  
COMMISSION IN OPPOSITION TO THE  
CONSUMERS POWER COMPANY REQUEST TO  
DELAY BRINGING ITS J.H. CAMPBELL AND  
B.C. COBB POWER PLANTS INTO COMPLIANCE  
WITH THE MICHIGAN "ONE PERCENT OR  
EQUIVALENT SULPHUR IN FUEL" RULE.**

**GRAND HAVEN, MICHIGAN.  
NOVEMBER 28, 1983.**



**Ministry  
of the  
Environment**

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Presentation to : the Michigan  
air pollution control commission  
in opposition to the Consumers  
Power Company to delay  
78164

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## 1. INTRODUCTION

### 1.1 THE ISSUE

THE CONSUMERS POWER COMPANY HAS APPLIED TO THE MICHIGAN AIR POLLUTION CONTROL COMMISSION FOR AN EXTENSION TO A CONSENT ORDER WHICH WOULD PERMIT THE COMPANY TO CONTINUE TO BURN COAL WITH A SULPHUR CONTENT HIGHER THAN ONE PERCENT AT ITS B.C. COBB AND J.H. CAMPBELL POWER PLANTS BEYOND DECEMBER 31, 1984. UNDER THIS CONSENT ORDER, THE J.H. CAMPBELL PLANT IS PRESENTLY PERMITTED TO BURN UP TO 3.05% SULPHUR COAL ON AN ANNUAL BASIS WHILE THE B.C. COBB PLANT IS CURRENTLY ALLOWED TO USE 2.5% SULPHUR COAL.

CONSUMERS POWER IS APPLYING TO BE ALLOWED TO BURN UP TO ~~2.6% SULPHUR COAL ON AN ANNUAL BASIS AT THE CAMPBELL PLANT~~ AND A MAXIMUM 2.92% SULPHUR COAL DURING ANY GIVEN 24-HOUR PERIOD. THE COMPANY IS ALSO REQUESTING THAT THE ~~CORB PLANT~~ BE PERMITTED TO BURN, ON AN ~~ANNUAL AVERAGE~~, ~~1.7% SULPHUR COAL~~, WITH A MAXIMUM 2.6% SULPHUR DURING A 24-HOUR PERIOD. THE COMPANY IS REQUESTING THAT IT BE ALLOWED TO USE THESE FUELS FROM JANUARY 1, 1985 UNTIL DECEMBER 31, 1990.

UNDER PART 4 OF RULE 336.1401 OF THE MICHIGAN AIR POLLUTION CONTROL COMMISSION, CONSUMERS POWER COMPANY WOULD OTHERWISE BE REQUIRED TO BURN COAL WITH AN AVERAGE ONE PERCENT SULPHUR CONTENT OR APPLY CONTROL TECHNOLOGIES THAT WILL ACHIEVE EQUIVALENT TOTAL SO<sub>2</sub> EMISSIONS.

THE MICHIGAN AIR POLLUTION CONTROL COMMISSION MUST DECIDE WHETHER TO GRANT A NEW CONSENT ORDER OR TO DENY THE REQUEST. IT IS UNDERSTOOD THAT THE COMMISSION WILL CONSIDER A VARIETY OF EVIDENCE AND RECOMMENDATIONS. ONTARIO SUBMITS THIS BRIEF IN AN ATTEMPT TO ASSIST THE COMMISSION IN MAKING ITS DECISION.

## 1.2 MICHIGAN'S ACCOMPLISHMENTS

IN 1972, THE STATE OF MICHIGAN ADOPTED A ONE PERCENT SULPHUR IN FUEL REGULATION FOR MAJOR SOURCES AND A ONE AND A HALF PERCENT SULPHUR IN FUEL RULE FOR MINOR SOURCES. ALL SOURCES WERE ALLOWED A ~~PHASED APPROACH~~ TO COMPLY WITH THESE REGULATIONS. FIRST STEPS WERE REQUIRED TO BE IN PLACE BY 1975 AND COMPLETE COMPLIANCE WAS SCHEDULED FOR 1978. MOST SOURCES WERE IN COMPLIANCE BY THIS DATE; HOWEVER, SEVERAL SOURCES REQUESTED EXTENSIONS.

ONTARIO COMMENDS MICHIGAN FOR ITS SO<sub>2</sub> ABATEMENT MEASURES TO DATE. SOURCES IN MICHIGAN HAVE REDUCED THEIR TOTAL STATEWIDE EMISSIONS OF SO<sub>2</sub> SINCE 1974 BY 54%. THIS IS AN ENVIABLE RECORD AND FAR SURPASSES MANY OF MICHIGAN'S NEIGHBOURING STATES.

ANOTHER EXAMPLE OF MICHIGAN'S FIRM STANCE WITH RESPECT TO EMISSION CONTROLS IS THE RECENT DECISION BY THE COMMISSION TO DENY A SIMILAR EXTENSION REQUEST FROM DETROIT EDISON FOR ITS MONROE POWER PLANT. THIS ACTION ILLUSTRATES MICHIGAN'S COMMITMENT TO SULPHUR DIOXIDE ABATEMENT. ONTARIO TRUSTS THAT THIS COMMITMENT WILL BE REAFFIRMED AT THIS HEARING.

### 1.3 ONTARIO'S POSITION

AT THIS HEARING, THERE ARE MANY SIGNIFICANT ISSUES THAT THE COMMISSION MUST CONSIDER IN REACHING ITS DECISION. ONE OF THESE ISSUES CONCERNS TRANSBOUNDARY FLOWS OF AIR POLLUTANTS AND THE RESULTING ACID DEPOSITION WITHIN THE STATE OF MICHIGAN AND NEIGHBOURING JURISDICTIONS SUCH AS ONTARIO.

TRANSBOUNDARY AIR POLLUTION DOES NOT RESPECT INTERSTATE OR INTERNATIONAL BOUNDARIES. WHAT GOES UP FROM ONE BACKYARD CAN, AND OFTEN DOES, COME DOWN IN ANOTHER. THIS IS CERTAINLY THE CASE WITH ACIDIC DEPOSITION AND ITS PRECURSORS, SULPHUR DIOXIDE AND NITROGEN OXIDES. CONSEQUENTLY, POLLUTION CONTROL TO PROTECT THE NORTH AMERICAN ENVIRONMENT MUST BE A SHARED RESPONSIBILITY AND COMMITMENT.

AS A RESULT, ONTARIO HAS AN INTEREST IN ANY HEARING THAT MAY INCREASE THE ATMOSPHERIC LOADING OF POLLUTANTS SUCH AS SO<sub>2</sub>, OR THAT MAY DELAY PROGRAMS AND EFFORTS TO DECREASE THE ATMOSPHERIC BURDEN OF THESE CONTAMINANTS.

ONTARIO, THEREFORE, MAINTAINS THAT:

- THE SO<sub>2</sub> EMISSIONS FROM THE COBB AND CAMPBELL POWER PLANTS CANNOT BE CONSIDERED IN ISOLATION. THEY CONTRIBUTE TO THE AGGREGATE OF EMISSIONS IN NORTHEASTERN NORTH AMERICA WHICH, BEING THE PRECURSORS TO ACID DEPOSITION, ARE A CAUSE OF ADVERSE EFFECTS TO

SENSITIVE ECOSYSTEMS IN MICHIGAN AND OTHER JURISDICTIONS;

- GRANTING THE CONSUMERS POWER COMPANY REQUESTS WOULD BE IN VIOLATION OF THE SPIRIT OF THE MEMORANDUM OF INTENT ON TRANSBOUNDARY AIR POLLUTION SIGNED BY CANADA AND THE UNITED STATES ON AUGUST 5, 1980, IN WHICH BOTH COUNTRIES AGREED TO "PROMOTE VIGOROUS ENFORCEMENT OF EXISTING LAWS AND REGULATIONS";
- AN IMPORTANT PRECEDENT HAS BEEN SET BY THE COMMISSION IN ITS DECISION TO DENY DETROIT EDISON'S REQUEST TO DELAY COMPLIANCE WITH PART 4 OF RULE 336.1401. IN PARTICULAR, THE LEVEL OF SULPHUR REQUESTED FOR THE CAMPBELL PLANT IS EVEN HIGHER THAN THE 1.9% REQUESTED BY DETROIT EDISON FOR ITS MONROE PLANT;
- IN THE COMPANY'S SUBMISSIONS TO THE COMMISSION, THE COSTS OF COMPLYING WITH RULE 336.1401(4) TO CONSUMERS POWER HAVE LIKELY BEEN OVERESTIMATED WHILE THE POTENTIAL BENEFITS HAVE BEEN UNDERSTATED. IT IS LIKELY, THEREFORE, THAT THE BENEFITS TO BOTH MICHIGAN AND ONTARIO RESIDENTS ARE, IN FACT, AT LEAST COMMENSURATE WITH THE COSTS INDICATED BY THE COMPANY'S COST-BENEFIT ANALYSES.

THE FOLLOWING CHAPTERS WILL EXPAND ON THE ABOVE ARGUMENTS IN ORDER TO SUPPORT ONTARIO'S POSITION THAT THERE IS A STRONG CASE FOR THE COMMISSION TO ENFORCE THE MICHIGAN "ONE PERCENT OR EQUIVALENT SULPHUR IN FUEL" RULE WITH RESPECT TO BOTH THE COBB AND CAMPBELL PLANTS.

## 2. CHARACTERISTICS OF CONSUMERS POWER COMPANY

### 2.1 FINANCIAL SITUATION

CONSUMERS POWER COMPANY IS AN INVESTOR-OWNED UTILITY THAT SUPPLIES ELECTRICITY AND GAS TO CUSTOMERS THROUGHOUT THE LOWER PENINSULA OF THE STATE OF MICHIGAN. AS OF JANUARY 1, 1981, CONSUMERS POWER HAD A TOTAL GENERATING CAPACITY OF 6,647,800 KILOWATTS (KW) (ELECTRIC WORLD 1982, P. 372). IN 1980, THE SYSTEM HAD SUMMER AND WINTER GENERATION PEAKS OF 4,673,272 KW AND 4,527,140 KW RESPECTIVELY (ELECTRIC WORLD 1982, P. 372).

AS SUMMARIZED IN TABLE 2.1, CONSUMERS POWER SOLD ABOUT 25,684 MILLION KILOWATT HOURS (KWH) OF ELECTRICITY DURING 1981. THIS IS A SLIGHT INCREASE OVER 1980 BUT A DECLINE FROM 26,797 MILLION KWH IN SALES DURING 1979. NEVERTHELESS, TOTAL REVENUES FROM ELECTRICITY ROSE FROM \$1,122.8 MILLION IN 1979 TO \$1,386.8 MILLION FOR 1981. MOREOVER, BETWEEN 1979 AND 1981, COMPANY PROFITS ("NET INCOME FROM GAS AND ELECTRICITY") INCREASED BY 21.6% FROM \$203.8 MILLION IN 1979 TO \$247.8 MILLION DURING 1981 (MOODY'S PUBLIC UTILITY MANUAL 1981, P. 562).

ACCORDING TO THE MICHIGAN PUBLIC SERVICE COMMISSION (NOVEMBER 8, 1983), THE COMPANY'S ELECTRICITY RATES HAVE INCREASED, ON AVERAGE, BY ONLY ABOUT 6 OR 7% BETWEEN 1981 AND 1983. NEVERTHELESS, THE COMPANY HAS STEADILY INCREASED ITS DIVIDEND PAYMENTS OVER THE YEARS. DIVIDENDS PAID TOTALLED \$203.2 MILLION IN 1981. STATED

COMMISSIONED IN 1980, CURRENTLY BURNS COAL WITH 0.64% SULPHUR (MICHIGAN DEPARTMENT OF NATURAL RESOURCES). THIS BOILER OR UNIT IS SUBJECT TO NEW SOURCE PERFORMANCE STANDARDS REQUIRED BY U.S. FEDERAL LAW AND SO IS NOT INCLUDED IN THE COMPANY'S REQUEST CURRENTLY UNDER CONSIDERATION.

THE COBB PLANT HAS FIVE COAL-FIRED UNITS. UNITS 1 TO 3 HAVE CAPACITIES OF 66,000 KW EACH WHILE UNITS 4 AND 5 ARE RATED AT 156,300 KW EACH.

UNDER THE EXISTING CONSENT ORDERS, CAMPBELL UNITS 1 AND 2 HAVE A STATE IMPLEMENTATION PLAN (SIP) OBJECTIVE OF 3.05% SULPHUR IN COAL WHILE COBB UNITS 1 TO 5 ARE OBLIGED TO USE COAL WITH 2.5% SULPHUR OR LESS ON AN ANNUAL BASIS.

IT IS IMPORTANT TO NOTE THAT THE COBB AND CAMPBELL PLANTS WERE EACH OPERATED AT LESS THAN 50% OF THEIR RATED CAPACITIES DURING 1982. A 70% CAPACITY FACTOR IS CONSIDERED NORMAL FOR A WELL-MAINTAINED POWER PLANT.

ACCORDING TO CONSUMERS POWER OFFICIALS, UNITS 1 AND 2 AT THE CAMPBELL PLANT ARE EXPECTED TO BE DECOMMISSIONED (CLOSED DOWN) BY 2008. UNITS 1 TO 3 AT COBB ARE SUPPOSED TO LAST UNTIL 1990 WHILE UNITS 4 AND 5 ARE EXPECTED TO TAKEN OUT OF SERVICE BY 1998.

IF CONSUMERS POWER IS GRANTED ITS REQUESTS AND ASSUMING THE PLANTS OPERATE AN AVERAGE OF 70% OF THE TIME, THE SO<sub>2</sub>

EMISSIONS FROM THE TWO PLANTS COULD TOTAL AS MUCH AS 165,200 TONS (150,000 METRIC TONS) PER YEAR.

IF CONSUMERS POWER COMPLIES WITH THE 1% SULPHUR IN FUEL REQUIREMENT, THE RESULTING TOTAL ANNUAL EMISSIONS FROM THE TWO PLANTS WOULD DEPEND ON THE OPERATION RATE OF THE TWO PLANTS. DURING 1982, THE PLANTS WERE RUN ONLY ABOUT 50% OF THE TIME. AS NOTED, A 70% CAPACITY FACTOR IS CONSIDERED NORMAL. AS INDICATED IN TABLE 2.3, THE PLANTS COULD GENERATE A TOTAL OF 95,700 TONS (87,000 METRIC TONS) OF SO<sub>2</sub> PER YEAR IF OPERATED AT A 70% CAPACITY FACTOR.

CONSEQUENTLY, COMPLIANCE WITH THE STATE RULES COULD REDUCE TOTAL ANNUAL SO<sub>2</sub> EMISSIONS BY AS MUCH AS 42% FROM WHAT MIGHT BE EMITTED IF CONSUMERS POWER WERE GRANTED ITS REQUESTS.

TABLE 2.1

## FINANCIAL AND ELECTRIC POWER PRODUCTION STATISTICS, CONSUMERS POWER COMPANY, 1975, 1979-1981

Item	1982	1981	1980	1979	1975
1. Total Elect. generation capacity (KW)	N/A	6,648,000	N/A	N/A	N/A
2. Total Elect. Sales (million Kwh)	N/A	25,684	25,519	26,797	22,910
3. Total Revenues (Electricity and Gas) (million \$)	N/A	2,637.9	\$2,294.9	\$1,989.4	\$1,330.9
4. Total Elect. Revenues (million \$)	N/A	1,386.8	1,264.4	1,222.8	752.9
5. Electricity Revenues as a % of Gross Revenues	N/A	52.6	56.3	56.4	56.6
6. Total Electric Operating Costs (million \$)	N/A	940.2	903.4	800.4	492.3
7. Income or Profits, Net of total gas and electricity operating cost (million \$)	N/A	247.8	223.8	203.8	100.7
8. Total Coal Burned (000 tons)	5,754	6,693.0	5,721.0	6,393.0	5,967 (1976)
9. Cost of Coal (million \$)	N/A	306.2	226.3	209.0	138.6 (1976)

Sources: Moody's Public Utility Manual 1981, Vols. 1 & 2.

Electric World 1982.

TABLE 2.2

## CHARACTERISTICS OF COAL-FIRED POWER PLANTS OWNED BY THE CONSUMERS POWER COMPANY

Plant	Location (town)	Generation Capacity (1) (MW)	Fuel Burned	Capacity Factor (1982)	% Sulphur in Coal		SO <sub>2</sub> Emissions 1982 (4) (000 tons)	Amount of Coal Burned (3) (000 tons)
					S.I.P. Objective (2)	Actual 1982 (3)		
1. B. C. Cobb	Muskegon	510	coal	0.47	2.5	2.42	42.5	923
2. J. H. Campbell	West Olive	1,440	coal, gas	0.45	Units 1,2 3.05	2.27	49.2	2,239
					Unit 3 0.7	0.64	15.2	
3. D. E. Karn	Essexville	1,767	coal	0.18	1.0	0.85	17.8	1,042
4. J. C. Weadock	Essexville	635	coal, gas	0.28	1.0	0.87	10.1	686
5. J. R. Whiting	Erie	346	coal, gas	0.66	1.0	0.79	14.2	865
TOTAL FOR CPC'S PLANTS		4,698	-	-	-	-	160.7 (5)	5,754

Sources: (1) U.S. Department of Energy 1979.

(2) U.S. Department of Energy 1982; Michigan Department of Natural Resources, Air Quality Division 1983.

(3) Ministry of the Environment 1982.

(4) Michigan Department of Natural Resources, Air Quality Division 1983.

(5) Emissions from coal only.

TABLE 2.3

ESTIMATED SO<sub>2</sub> EMISSIONS FROM THE COBB AND CAMPBELL PLANTS  
UNDER DIFFERENT SCENARIOS

Power Plant/Units	Annual SO <sub>2</sub> Emissions During 1982 (1)		Estimated Annual SO <sub>2</sub> Emissions if Company's requests were Granted		Estimated Annual Emissions After SO <sub>2</sub> Compliance with the 1% Sulphur in Fuel Rule	
	(capacity factor)	(000 tons)	(capacity factor)	(000 tons)	at 50% Capacity Factor	at 70% Capacity Factor
					(000 tons)	
B.C. Cobb Units 1-5	0.47	42.5	0.70	48.2	18.1	25.3
J.H. Campbell Units 1-2	0.45	64.4	0.70	117.0	50.3	70.4
		49.2		78.8	23.0	32.2
Unit 3		15.2		38.2	27.3	38.2
Total (000 metric tons)		106.9 (97.0)		165.2 (150.0)	68.4 (62.1)	95.7 (86.8)

- Sources: (1) Michigan Department of Natural Resources, Air Quality Division 1983.  
 (2) Estimated by Air Resources Branch, Ontario Ministry of the Environment assuming the use of 2.6% sulphur coal in Campbell units 1 and 2, 0.64% sulphur coal in Campbell units 3 and 1.95% sulphur coal in Cobb units 1 to 5.  
 (3) Estimated by Air Resources Branch, Ontario Ministry of the Environment.

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### 3. LEGAL AND POLICY CONSIDERATIONS

THE PRIMARY DUTY OF THE MICHIGAN AIR POLLUTION CONTROL COMMISSION IS TO PROTECT THE HEALTH AND WELFARE OF THE PEOPLE OF MICHIGAN. THIS IS ALSO THE MAIN OBJECTIVE OF MICHIGAN'S AIR POLLUTION CONTROL LAWS. HOWEVER, THE COMMISSION'S DUTIES ARE NOT CARRIED OUT IN A VACUUM. THE COMMISSION MUST INTERPRET AND APPLY THE LAWS IN THE CONTEXT OF A FRAMEWORK OF INTERNATIONAL LAW, PUBLIC POLICY AND A TRADITION OF COOPERATION BETWEEN THE STATE OF MICHIGAN AND THE PROVINCE OF ONTARIO IN THE MANAGEMENT OF OUR COMMON AIR RESOURCES.

MICHIGAN'S AIR POLLUTION CONTROL LAWS MUST BE INTERPRETED IN LIGHT OF THE FACT THAT MICHIGAN AND ONTARIO SHARE A COMMON AIRSHED, COMMON BODIES OF WATER AND A COMMON PROBLEM OF ACIDIC DEPOSITION. THE AIR WHICH IS OVER MICHIGAN TODAY MAY BE OVER ONTARIO TOMORROW, AND VICE VERSA. IT IS NOT ONLY IN THE INTERESTS OF ONTARIO TO CONTROL EMISSIONS THAT MAY CONTRIBUTE TO ACID RAIN, BUT ALSO IN THE INTERESTS OF THE CITIZENS OF MICHIGAN, IN LIGHT OF RECENT EVIDENCE OF A POTENTIAL FOR ACIDIC DEPOSITION TO DESTROY FISH AND OTHER AQUATIC ORGANISMS IN THE UPPER MICHIGAN PENINSULA. (SEE CHAPTER 5.)

ONTARIO IS SUBJECT TO ACIDIC DEPOSITION WHICH IS ALREADY RESULTING IN HARMFUL EFFECTS ON ONTARIO'S LAKES AND AQUATIC LIFE. THERE IS EVIDENCE THAT EMISSIONS FROM POWER PLANTS IN THE EASTERN AND MIDWESTERN UNITED STATES

SIGNIFICANTLY CONTRIBUTE TO ACIDIC DEPOSITION. SINCE COAL-FIRED POWER PLANTS ARE A SIGNIFICANT SOURCE OF ACIDIC DEPOSITION, THIS GIVES THE PROVINCE OF ONTARIO A SIGNIFICANT INTEREST IN THE OUTCOME OF ANY PROCEEDINGS THAT MAY AFFECT THE QUANTITY OF ALLOWABLE SULPHUR DIOXIDE EMISSIONS FROM ANY OF THESE POWER PLANTS, INCLUDING THE COBB AND CAMPBELL PLANTS.

THE EVIDENCE THAT EMISSIONS FROM THE COBB AND CAMPBELL POWER PLANTS DEPOSIT ACID-FORMING SUBSTANCES IN ONTARIO IS ALSO EVIDENCE THAT THE SAME EMISSIONS ARE DEPOSITING ACID-FORMING SUBSTANCES IN THE UPPER MICHIGAN PENINSULA, AS IN MANY INSTANCES THE SAME BODY OF AIR PASSES OVER THE UPPER MICHIGAN PENINSULA BEFORE ARRIVING IN ONTARIO. UNDER THESE CIRCUMSTANCES, A DECISION TO HELP ONTARIO IS ALSO A DECISION TO HELP MICHIGAN.

THE FOLLOWING WILL HIGHLIGHT CERTAIN ASPECTS OF THE LEGAL AND POLICY CONSIDERATIONS RELEVANT TO THESE DELIBERATIONS.

UNDER THE PRINCIPLE SET OUT IN THE TRAIL SMELTER CASE, THAT NO COUNTRY HAS THE RIGHT TO POLLUTE A NEIGHBOURING COUNTRY, WE WOULD SUGGEST THAT IT DOES NOT MATTER THAT THE COBB AND CAMPBELL PLANTS ARE ONLY TWO OF MANY POWER PLANTS WHOSE EMISSIONS SIGNIFICANTLY CONTRIBUTE TO THE ATMOSPHERIC BURDEN WHICH IS DETRIMENTALLY AFFECTING BOTH THE ONTARIO AND MICHIGAN ENVIRONMENTS. THE FACT THAT NO SINGLE SOURCE OF EMISSIONS MAY BY ITSELF BE A MAJOR

CONTRIBUTOR TO ACIDIC RAIN AND DEPOSITION DOES NOT EXCUSE ANY FAILURE TO DEAL WITH EACH SOURCE INDIVIDUALLY. WHEN CONFRONTED WITH HARM CAUSED BY POLLUTION FROM MANY SOURCES, WHERE THERE IS DIFFICULTY IN SEGREGATING AND MEASURING THE IMPACTS OF INDIVIDUAL SOURCES, THE COURTS HAVE STILL BEEN ABLE TO DESIGN EFFECTIVE REMEDIES BY APPLYING TRADITIONAL TORT PRINCIPLES. FOR EXAMPLE, THE SUPREME COURT OF THE UNITED STATES HAS RECOGNIZED TRADITIONAL PRINCIPLES OF TORT LAW IN THE CONTEXT OF INTERSTATE AIR OR WATER POLLUTION. THE COURT HAS FASHIONED A FEDERAL COMMON LAW OF NUISANCE.

THUS, THE SUPREME COURT HAS IMPOSED  
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O  
IT IS NO

(ILLINOIS V. MILWAUKEE, 406 U.S. 91 (1972)). THE FACT THAT EACH CONTRIBUTOR MAY BE JOINTLY AND SEVERALLY LIABLE FOR DAMAGE HAS ALSO BEEN RECOGNIZED BY OTHER U.S. COURTS (MICHIE V. GREAT LAKES STEEL, 495 F. 2d 13, 4 ERL 20324 (6th CIRCUIT 1974), CERT. DENIED 419 IN THE U.S. 997, 95S. CP. 310 (1974)).

THE COURTS, OF COURSE, APPLY THESE PRINCIPLES WITHOUT THE NEED FOR EXPLICIT STATUTORY LANGUAGE AND WE WOULD SUGGEST THAT THE STATE OF MICHIGAN SHOULD APPLY THE SAME KIND OF REASONING PROCESS IN REACHING ITS DECISION IN THIS CASE.

A FURTHER INDICATION THAT THE STATE LEGISLATURE INTENDS THE COMMISSION TO CARRY OUT ITS MANDATE IN A SPIRIT OF COOPERATION WITH THE PROVINCE OF ONTARIO IS THE

[REDACTED] BY THE

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] THIS

"MEMORANDUM OF UNDERSTANDING ON TRANSBOUNDARY AIR POLLUTION CONTROL IN SOUTHWESTERN ONTARIO - SOUTHEASTERN MICHIGAN AREA" RECITES THAT THE TWO GOVERNMENTS ARE INTENT UPON ACCELERATING CONTROL PROGRAMS TO IMPROVE AIR QUALITY IMPAIRED BY EXISTING SOURCES OF AIR POLLUTION IN THE DETROIT AND ST. CLAIR RIVER AREA AND DESIRE TO ASSURE COOPERATION TO PREVENT THE CREATION OF NEW SOURCES OF TRANSBOUNDARY AIR POLLUTION. IT ESTABLISHES A NUMBER OF PROGRAMS INCLUDING CONTROL OVER POINT SOURCES OF POLLUTION, MONITORING AND SURVEILLANCE OF AIR QUALITY, MAINTENANCE OF JOINT PROCEDURES FOR ACTIONS TO CONTROL AND PREVENT AIR POLLUTION EPISODES WHICH MAY BE OBSERVED OR PREDICTED, AND REGULAR EXCHANGE OF AIR QUALITY DATA AND REPORTS OF PROGRESS OF COMPLIANCE WITH ABATEMENT SCHEDULES.

ALSO, WITH RESPECT TO INTERNATIONAL AGREEMENTS, ONTARIO WISHES TO DRAW TO THE ATTENTION OF THE COMMISSION THE

[REDACTED]

[REDACTED]

[REDACTED]

~~STATES~~. IN THIS DOCUMENT, THE PARTIES DECLARED THEIR INTENTION "TO DEVELOP A BILATERAL AGREEMENT WHICH WILL REFLECT AND FURTHER THE DEVELOPMENT OF EFFECTIVE DOMESTIC CONTROL PROGRAMS AND OTHER MEASURES TO COMBAT TRANSBOUNDARY AIR POLLUTION".

BOTH PARTIES AGREED TO TAKE CERTAIN INTERIM ACTIONS PENDING CONCLUSION OF SUCH AN AGREEMENT. THESE INTERIM ACTIONS INCLUDED THE FOLLOWING UNDERTAKINGS WITH RESPECT TO CONTROL MEASURES:

"TO COMBAT TRANS-BOUNDARY AIR POLLUTION BOTH GOVERNMENTS SHALL:

(A) DEVELOP DOMESTIC AIR POLLUTION CONTROL POLICIES AND STRATEGIES, AND AS NECESSARY AND APPROPRIATE, SEEK LEGISLATIVE OR OTHER SUPPORT TO GIVE EFFECT TO THEM;

•  
(B) PROMOTE VIGOROUS ENFORCEMENT OF EXISTING LAWS AND REGULATIONS AS THEY REQUIRE LIMITATIONS OF EMISSIONS FROM NEW, SUBSTANTIALLY MODIFIED AND EXISTING FACILITIES IN A WAY WHICH IS RESPONSIVE TO THE PROBLEMS OF TRANSBOUNDARY AIR POLLUTION; AND

(C) SHARE INFORMATION AND CONSULT ON ACTIONS BEING TAKEN PURSUANT TO (A) AND (B)."

WITH REGARD TO THE GOAL SHARED BY BOTH GOVERNMENTS TO PROMOTE THE VIGOROUS ENFORCEMENT OF EXISTING LAWS AND REGULATIONS, ONTARIO WOULD LIKE TO POINT OUT THAT THIS GOAL IS CONSISTENT WITH THE RULES OF THE STATE OF MICHIGAN GOVERNING HOW THE COMMISSION WILL DECIDE ON REQUESTS FOR EXTENSIONS OF NON-COMPLIANCE WITH STATE STANDARDS, IN PARTICULAR, THE REQUIREMENT THAT EXTENSIONS WILL ONLY BE GIVEN WHEN PROGRESS TOWARDS ULTIMATE COMPLIANCE IS BEING DEMONSTRATED. TO DATE, NO COMMITMENT TO COMPLIANCE HAS BEEN DEMONSTRATED AND BOTH THE CAMPBELL AND COBB PLANTS HAVE RECEIVED PREVIOUS EXTENSIONS.

ONTARIO URGES THE COMMISSION TO TAKE ACCOUNT OF THE ABOVE UNDERTAKINGS AND TO MAKE ITS DECISION WITH RESPECT TO THESE REQUESTS FOR EXTENSIONS OF NON-COMPLIANCE IN A MANNER CONSISTENT WITH SUCH UNDERTAKINGS. ~~ONTARIO IS NOT ASKING THE STATE TO ENFORCE LAWS TO PREVENT SUCH PROBLEMS OF TRANSBOUNDARY POLLUTION, BUT ONLY TO ENFORCE ITS EXISTING LAWS AND REGULATIONS.~~ TO FAIL TO REQUIRE SUBSTANTIAL PROGRESS WOULD BE CONTRARY NOT ONLY TO MICHIGAN'S OWN CRITERIA FOR GRANTING EXTENSIONS, BUT ALSO TO THE SPIRIT OF THE MEMORANDUM OF INTENT. WE URGE THAT, PENDING THE FINALIZATION OF AN INTERNATIONAL AGREEMENT ON TRANSBOUNDARY AIR POLLUTION, THE STATE OF MICHIGAN SHOULD USE ITS BEST EFFORTS TO MAKE BOTH THE COBB AND CAMPBELL PLANTS COMPLY WITH PRESENT LIMITS, RATHER THAN ALLOW EXTENSIONS WHICH MAY IN EFFECT AMOUNT TO RAISING THOSE LIMITS.

#### 4. THE LRTAP PHENOMENON

THE RECOGNITION THAT AIR POLLUTANTS CAN BE TRANSPORTED FAR BEYOND THEIR LOCAL ORIGINS IS NOT NEW. ONE OF THE EARLIEST REFERENCES TO THE EXISTENCE OF A LONG RANGE TRANSPORT PHENOMENON OCCURRED IN THE MID 19TH CENTURY (SMITH 1872). THE FREQUENCY OF SUCH REFERENCES HAS INCREASED OVER THE PAST ONE HUNDRED YEARS.

HOWEVER, ACTUAL SCIENTIFIC INVESTIGATIONS OF THE VARIOUS ASPECTS OF THIS PROBLEM HAVE ONLY BEEN INCREASING OVER THE PAST 15 TO 20 YEARS. THE FUNDAMENTAL FINDINGS OF THIS RESEARCH HAVE ESTABLISHED THAT A NUMBER OF PRIMARY AND SECONDARY AIR POLLUTANTS, INCLUDING PARTICULATES, CARBON MONOXIDE, OZONE, SULPHATES, NITRATES AND VARIOUS ORGANIC COMPOUNDS CAN UNDERGO LONG RANGE TRANSPORT. IN FACT, LONG RANGE TRANSPORT HAS NOT ONLY BEEN DOCUMENTED ON A REGIONAL SCALE (100 - 300 KM), BUT ALSO ON THE CONTINENTAL (500 - 1000 KM) AND EVEN THE HEMISPHERIC OR GLOBAL (1000 - 5000 KM) SCALES. HOWEVER, DUE TO THE AVAILABILITY OF CONSIDERABLY MORE DATA ON THE REGIONAL AND CONTINENTAL SCALES, OBSERVATIONS CAN BE MADE TO LINK SUCH TRANSPORT TO VISIBILITY DEGRADATION, AQUATIC AND TERRESTRIAL IMPACTS, MATERIALS DAMAGE, ETC.

IN THE LAST 10 YEARS, INTENSIVE FIELD INVESTIGATIONS HAVE BEEN INITIATED IN BOTH EUROPE AND NORTH AMERICA. THESE STUDIES HAVE CENTERED ON INCREASING THE UNDERSTANDING OF THE CYCLES AND BUDGETS OF SULPHUR POLLUTION. THE VARIOUS COMPONENTS OF THESE STUDIES HAVE INCLUDED

CHARACTERIZATION AND DEVELOPMENT OF EMISSION INVENTORIES;  
IMPROVEMENT OF THE UNDERSTANDING OF THE DYNAMIC  
MECHANISMS AND PROCESSES LEADING TO LONG RANGE TRANSPORT;  
POLLUTANT TRANSFORMATION AND POLLUTANT REMOVAL (WET/DRY  
DEPOSITION); THE MEASUREMENT OF HORIZONTAL AND VERTICAL  
SULPHUR DISTRIBUTION (MEASUREMENT AND ANALYSIS OF  
PARTICULATES AND PRECIPITATION CHEMISTRY); AND THE  
DEVELOPMENT AND REFINEMENT OF MESOSCALE MODELS.

AS A RESULT OF THESE AND OTHER STUDIES, A NUMBER OF IMPORTANT FINDINGS ON THE NATURE OF LONG RANGE TRANSPORT OF NITROGEN AND SULPHUR OXIDES (INCLUDING THEIR TRANSFORMATION PRODUCTS) IN EASTERN NORTH AMERICA CAN BE STATED. THESE FINDINGS INCLUDE:

- THE AIR MASSES IN THE LATE SUMMER HAVE THE GREATEST  
POTENTIAL FOR FORMATION AND TRANSPORT OF HIGH  
CONCENTRATIONS OF SULPHATE INTO THE NORTHEASTERN  
UNITED STATES AND INTO EASTERN CANADA. CONVECTIVE  
SHOWERS ARE ALSO TYPICAL OF THESE AIR MASSES WHICH CAN  
LEAD TO ACID PRECIPITATION.
- THE MECHANISMS OF THE CHEMICAL REACTIONS ASSOCIATED  
WITH ACIDIC DEPOSITION ARE QUITE COMPLEX AND DEPEND ON  
A HOST OF VARIABLES. THEY RANGE FROM THE PHYSICAL  
PROPERTIES OF THE POLLUTANTS TO WEATHER CONDITIONS AND  
THE PRESENCE OF CATALYTIC OR INTERACTING AGENTS. EVEN  
THOUGH THESE CHEMICAL PROCESSES ARE NOT VERY WELL

UNDERSTOOD, IT DOES APPEAR THAT THE [REDACTED]  
[REDACTED] (NATIONAL ACADEMY OF  
SCIENCE 1983) AND THAT [REDACTED]

[REDACTED] 1000 TO 2000 KM OVER THREE TO FIVE

[REDACTED]

- ACIDIC PRECIPITATION HAS RECEIVED INTENSIVE STUDY IN SOUTHERN SCANDINAVIA. THIS RESEARCH HAS SHOWN THAT ACIDIC RAIN IN NORWAY AND SWEDEN PRIMARILY RESULTS FROM LARGE SCALE TRANSPORT OF NITROGEN AND SULPHUR OXIDE EMISSIONS IN GREAT BRITAIN AND THE INDUSTRIAL REGIONS OF CONTINENTAL WESTERN EUROPE (E.G. WEST GERMANY, BELGIUM, HOLLAND, FRANCE).

- AIR POLLUTION PROBLEMS ASSOCIATED WITH SULPHUR COMPOUNDS ARE OF A LARGE-REGIONAL NATURE IN EASTERN NORTH AMERICA, AFFECTING BOTH CANADA AND THE UNITED STATES. POLLUTION PROBLEMS ON THIS SCALE RESULT FROM THE ATMOSPHERIC TRANSPORT OF EMISSIONS OVER DISTANCES OF HUNDREDS TO THOUSANDS OF KILOMETRES DOWNWIND OF LARGE INDUSTRIAL REGIONS. [REDACTED] FREQUENTLY, CONTROL STRATEGIES SUCH AS THE USE OF VERY TALL STACKS, THROUGH WHICH INCREASED EMISSIONS BECAME ALLOWABLE, CONTRIBUTED TO THE WORSENING OF REGIONAL SCALE PROBLEMS.

IMPACTS OF THE TRANSPORTED POLLUTANTS ARE THE RESULT OF THEIR ATMOSPHERIC DEPOSITION BY VARIOUS WET AND DRY MEANS. DATA FROM PRECIPITATION COLLECTORS OPERATED IN THE DORSET AREA OVER ALMOST A THREE YEAR PERIOD, COMBINED

WITH BACK TRAJECTORY ANALYSES, (KURTZ AND SCHEIDER 1980),  
SHOWED THAT ABOUT [REDACTED]  
MOREOVER, [REDACTED]  
AT THIS [REDACTED]  
FROM THE [REDACTED] SOUTHWEST. COMPARATIVELY, A SMALL  
PERCENTAGE OF THE LOADINGS CAME FROM THE NORTH AND  
NORTHWEST WHERE MAJOR ONTARIO SOURCES ARE LOCATED.

WHILE BACK TRAJECTORY ANALYSIS CAN TELL US THE DIRECTION  
FROM WHICH THE AIR HAS ORIGINATED, IT CANNOT QUANTIFY THE  
AMOUNT OR PERCENTAGE OF CONTRIBUTION THAT INDIVIDUAL  
SOURCES OR AGGREGATES OF SOURCES HAVE ON A RECEPTOR  
AREA. FOR SUCH AN ANALYSIS, ONTARIO UTILIZES COMPUTER  
MODELS WHICH SIMULATE THE ATMOSPHERE AND THE BEHAVIOUR OF  
POLLUTANTS EMITTED INTO IT.

UNTIL A FEW YEARS AGO, ENVIRONMENTALISTS WERE PRIMARILY  
CONCERNED WITH AIR QUALITY IN THE VICINITY OF A POLLUTANT  
SOURCE. CONCENTRATIONS WERE CONSIDERED HIGH IF THEY WERE  
ABOVE LEVELS DETERMINED TO BE HARMFUL TO PLANTS AND HUMAN  
HEALTH. USING THIS CRITERION, EVEN LARGE POLLUTANT  
SOURCES COULD BE CONSIDERED TO HAVE LITTLE EFFECT BEYOND  
DISTANCES OF THE ORDER OF TENS OF KILOMETRES FROM THE  
SOURCE. THIS WAY OF LOOKING AT POLLUTION IGNORED THE  
EFFECTS OF THE LARGE FRACTION OF THE EMISSIONS WHICH LEFT  
THIS REGION OF "LOCAL" AIR QUALITY EFFECTS AND THE  
FORMATION OF SECONDARY POLLUTANTS DUE TO CHEMICAL  
TRANSFORMATIONS.

IT IS TO BE NOTED THAT BY APPLYING THE CONVENTIONAL SHORT RANGE MODELS RECOMMENDED BY EPA, THAT ALL THE POLLUTANTS ESCAPE TO GREATER DISTANCES, ALTHOUGH IN SMALL CONCENTRATIONS. IF WE APPLY DRY AND WET DEPOSITION TO THE PLUME, THEN APPROXIMATELY 30 TO 90% OF THE POLLUTANTS WOULD ESCAPE TO GREATER DISTANCES DEPENDING ON THE PLUME ELEVATION. THIS IS ASSUMING THAT 10% OF THE TIME THE PLUME ENCOUNTERS PRECIPITATION AT THE RELEASE POINT.

IT IS ONLY RECENTLY THAT KNOWLEDGE OF THE CUMULATIVE EFFECT OF SMALL CONCENTRATIONS FROM A LARGE NUMBER OF SOURCES HAS BECOME COMMONPLACE. SECONDARY POLLUTANTS FROM SEVERAL SOURCES CAN BE HIGH AT DISTANCES OF HUNDREDS OF KILOMETRES FROM THE SOURCE REGION. FURTHERMORE, THE OCCURRENCE OF ACIDIC RAIN HAS FORCED US TO REDEFINE THE MEANING OF "HIGH" AS APPLIED TO LOCAL AIR QUALITY.

ANALYSIS OF METEOROLOGY DURING HIGH TOTAL SUSPENDED PARTICULATES EPISODES HAS SHOWN THE ROLE OF LONG RANGE TRANSPORT. MATHEMATICAL MODELLING HAS ALSO INDICATED THE EXTENT OF POLLUTION CAUSED BY LONG RANGE TRANSPORT. THESE MODELS ALSO DETERMINE THE SOURCE-RECEPTOR RELATIONSHIPS AND DEVELOP EMISSION CONTROL STRATEGIES.

IN RESPONSE TO THESE EVOLVING NEEDS, ~~ONTARIO HAS~~  
~~DEVELOPED A RATIONALLY RESPECTED LONG RANGE~~  
~~SULPHUR DIOXIDE MODEL~~ (VENKATRAM  
ET AL 1982). THESE HAVE BEEN COMPUTED ON A PERCENTAGE  
BASIS FOR RECEPTOR AREAS IN BOTH CANADA AND THE UNITED

statistical

STATES WHICH ARE SENSITIVE TO ACIDIC DEPOSITION. ONTARIO HAS USED THE RESULTS OF THIS MODEL IN MAKING THE DECISIONS FOR THE CONTROL OF ONTARIO'S MAJOR SO<sub>2</sub> EMITTERS AND FOR THE DETERMINATION OF THE IMPACT OF SOURCES THAT ARE LOCATED IN THE EASTERN UNITED STATES AND NEIGHBOURING PROVINCES. ALSO, THE MODEL HAS BEEN USED AS A GUIDELINE TO PREDICT WHAT WILL HAPPEN IF SOURCES IN THE MIDWESTERN UNITED STATES HAVE THEIR STATE IMPLEMENTATION PLAN (SIP) LIMITS RELAXED (THE PROVINCE OF ONTARIO 1981).

THE SPECIFIC IMPACT OF THE COBB AND CAMPBELL POWER PLANTS, WHICH IN 1980 EMITTED A TOTAL OF 103 THOUSAND TONS OF SO<sub>2</sub>, ARE SHOWN IN FIGURES 4.1 AND 4.2. IT IS NOTED THAT THE

~~THE COBB AND CAMPBELL POWER PLANTS ARE LOCATED IN THE STATE OF MICHIGAN. A~~  
~~PORTION OF THE COBB AND CAMPBELL POWER PLANTS ARE LOCATED IN THE STATE OF MICHIGAN.~~  
~~0.7% OF THE COBB AND CAMPBELL POWER PLANTS ARE LOCATED IN THE STATE OF MICHIGAN.~~  
FOR THE COBB AND CAMPBELL POWER PLANTS IN THE STATE OF MICHIGAN.

COMPUTED AS A PERCENTAGE RELATIVE TO MICHIGAN AS A SOURCE AREA, THE COBB AND CAMPBELL CONTRIBUTION TO MUSKOKA-HALIBURTON IS APPROXIMATELY 12.5% AND TO THE UPPER PENINSULA APPROXIMATELY 7.5%.

Figure 4.1 COBB AND CAMPBELL POWER PLANTS

Deposition of wet sulphur over  
total wet sulphur in percentage  
(1980 emissions)

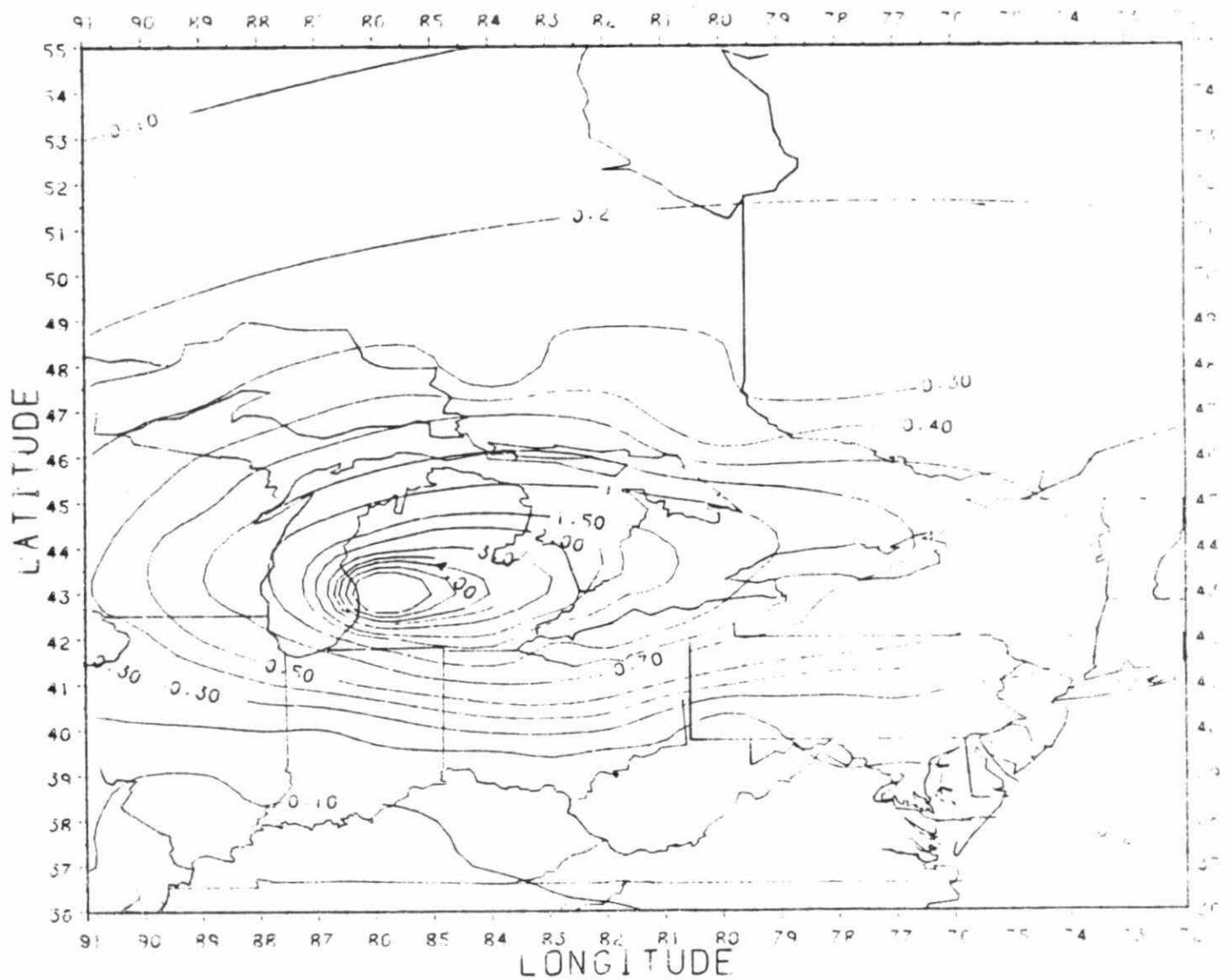
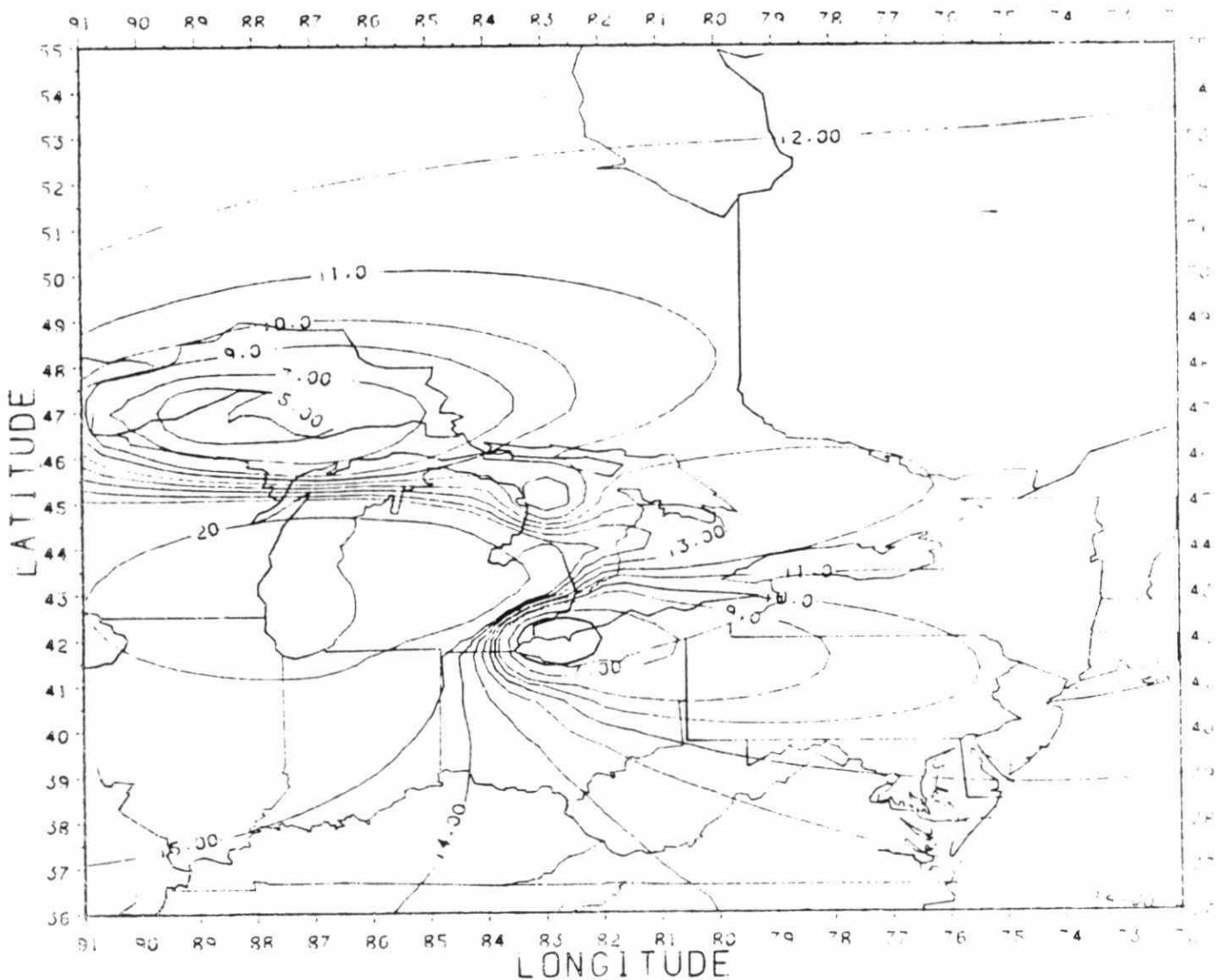


Figure 4.2 COBB AND CAMPBELL POWER PLANTS  
RELATIVE TO MICHIGAN STATE  
EMISSIONS (1980 emissions)

Deposition of wet sulphur over  
total wet sulphur in percentage



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## 5. EFFECTS OF ACIDIC DEPOSITION ON AQUATIC ECOSYSTEMS

### 5.1 INTRODUCTION

THE DETRIMENTAL EFFECTS OF ACIDIC DEPOSITION ON AQUATIC ECOSYSTEMS HAVE BEEN DOCUMENTED IN WESTERN EUROPE, PARTICULARLY SCANDINAVIA, AND IN SENSITIVE REGIONS OF NORTH AMERICA. IN THIS CHAPTER, THE EFFECTS OF ACIDIC DEPOSITION ON THE CHEMISTRY OF STREAMS AND LAKES IN ONTARIO ARE REVIEWED AND THE RESULTANT CHANGES IN AQUATIC BIOTA, ESPECIALLY FISH, ARE DISCUSSED. EFFECTS OF ACIDIC DEPOSITION ON AQUATIC RESOURCES IN THE STATE OF MICHIGAN ARE ALSO HIGHLIGHTED.

### 5.2 BACKGROUND

UNDER THE CURRENT PATTERN OF ACIDIC DEPOSITION, VIRTUALLY ALL OF THE LAKES LOCATED ON THE SENSITIVE PRECAMBRIAN SHIELD OF ONTARIO ARE BEING SUBJECTED TO ACID LOADINGS ABOVE "BACKGROUND" LEVELS. PRECIPITATION WITH PH NEAR

5.6. THE EXPECTED "BACKGROUND" VALUE CONTAINS ABOUT 2.5

UEQ L-1 OF ACID RESISTANCE. THE

BULK DEPOSITION ARE OF THE ORDER OF 100 LBS/ACRE/YEAR

AL 1979A) IN THE IMPORTANT RECREATIONAL AREA OF MUSKOKA-HALIBURTON (28 TO 36 TIMES "BACKGROUND" LEVELS). AS PRECAMBRIAN ONTARIO IS APPROXIMATELY 10% WATER SURFACE, MOST OF THE ACIDS BEING DEPOSITED FROM THE ATMOSPHERE FIRST COME INTO CONTACT WITH THE TERRESTRIAL ECOSYSTEM BEFORE REACHING THE AQUATIC SYSTEM. HERE, THE ACIDS

1 REACT WITH THE SOILS AND ROCK AND MAY BE ASSIMILATED OR NEUTRALIZED IN A VARIETY OF WAYS. PRINCIPAL AMONG THESE ARE WEATHERING REACTIONS AND ION EXCHANGE REACTIONS WHICH RELEASE  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $Na^{+}$ ,  $K^{+}$ ,  $Al^{3+}$  AND, TO A LESSER DEGREE,  $Fe^{2+}$  AND  $Mn^{2+}$  INTO THE RUNOFF WATERS DRAINING THE LAND. ASSOCIATED WITH THESE CATIONS (POSITIVELY CHARGED IONS) ARE ANIONS (NEGATIVELY CHARGED), PRINCIPALLY  $HCO_3^{-}$ . THEREFORE, IN ~~PRISTINE WATERS~~ RECEIVING LITTLE ACIDIC DEPOSITION OR THOSE NOT YET AFFECTED BY ACIDIC DEPOSITION, THE ~~ION CONCENTRATIONS ARE LOW~~, ~~MG<sup>2+</sup> AND NA<sup>+</sup> ARE THE MAJOR CATIONS~~. ~~H<sup>+</sup> IS THE MAJOR CATION~~ COMPONENT OF THE ~~WATER~~ NEUTRALIZING CAPACITY OF LAKES AND STREAMS. WATERS WITH LOW ALKALINITY ARE REGARDED AS SENSITIVE TO THE INPUT OF ACID SINCE THEY HAVE A LOW CAPACITY TO BUFFER THE pH (A MEASURE OF THE  $H^{+}$  OR ACIDITY LEVEL) AT ACCEPTABLE VALUES.

AS THE DEPOSITION OF ACIDS INCREASES, TERRESTRIAL WEATHERING REACTIONS CONTINUE TO NEUTRALIZE ACIDS, PERHAPS RESULTING IN AN INCREASE IN CATION LEVELS IN RUNOFF WATERS. HOWEVER, THESE ACID ASSIMILATION PROCESSES CANNOT CONTINUE TO NEUTRALIZE INCOMING ACIDS INDEFINITELY AT INCREASED RATES OF ACID LOADING. IF THE MATERIALS THAT ASSIMILATE THE ACIDS IN THE TERRESTRIAL SYSTEM ARE EXHAUSTED, OR MORE LIKELY, WHEN THE ASSIMILATION MECHANISMS CANNOT OPERATE FAST ENOUGH, THE ALKALINITY AND pH OF THE RUNOFF WATER DECLINE. ~~THE~~

~~REPLACED BY THE ANIONS ASSOCIATED WITH THE ACIDS, SUCH~~

[REDACTED] CAUSE  $H^+$  IS CAUSELY RETAINED IN THE  
TERRESTRIAL SYSTEM.  $SO_4^{2-}$  [REDACTED] THE DOMINANT ANION IN  
THE RUNOFF WATER. WHEN THE NATURAL TENDENCY OF STREAMS AND

[REDACTED] TO ZERO (pH 4.5-5.0), THEY BECOME  
[REDACTED] THUS, THE IONIC CONTENT OF ACIDIFIED WATERS  
IS DOMINATED BY  $H^+$  AND  $SO_4^{2-}$  WITH GREATER AMOUNTS OF  
METALS SUCH AS  $Al^{3+}$  PRESENT. IN SEVERE CASES, THESE  
CHEMICAL CHANGES EXIST ON A YEAR-ROUND BASIS (LONG-TERM  
ACIDIFICATION), WHILE IN LESS AFFECTED AREAS AND AT  
EARLIER STAGES OF ACIDIFICATION, THE CHEMICAL CHANGES  
OCCUR REVERSIBLY FOR SHORT TIME PERIODS SUCH AS THE  
SPRING SNOWMELT.

ONE OF THE CHANGES IN AQUATIC SYSTEMS IS ACCOMPANIED BY  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

ACIDIFICATION OF AQUATIC SYSTEMS IS ACCOMPANIED BY  
CHANGES IN ALL BIOLOGICAL COMMUNITIES. IN SOME CASES,  
THE IMMEDIATE CAUSE OF THE CHANGE IS  $H^+$  AND METAL  
(ESPECIALLY ALUMINUM) TOXICITY BUT OTHER CHANGES MAY HAVE  
MORE INDIRECT CAUSES SUCH AS ALTERATION OF THE LIGHT OR  
THERMAL REGIMES. THE BIOLOGICAL CONSEQUENCES OF  
ACIDIFICATION ARE SERIOUS AND EFFECTS HAVE BEEN OBSERVED  
ON BACTERIAL DECOMPOSITION, PHYTOPLANKTON, ZOOPLANKTON

AND BENTHIC INVERTEBRATES. THE MOST DRAMATIC EFFECTS ARE THOSE IN THE FISH POPULATIONS WHICH INCLUDE INCREASING METAL CONCENTRATIONS IN FISH FLESH, FISH "KILLS" ASSOCIATED WITH SHORT-TERM INCREASES IN ACID AND AL LEVELS IN WATERS AND ENTIRE LOSSES OF FISH POPULATIONS FROM ACIDIFIED LAKES.

### 5.3 AQUATIC EFFECTS IN MICHIGAN

WHILE IT IS NOT THE INTENT OF ONTARIO TO PRESENT A DETAILED CASE ON ACIDIC DEPOSITION AND ITS EFFECTS ON THE AQUATIC RESOURCES OF MICHIGAN, ONTARIO SUBMITS THAT EMISSIONS FROM THE CAMPBELL AND COBB GENERATING STATIONS CONTRIBUTE TO ACIDIC DEPOSITION IN THE STATE OF MICHIGAN.

SEVERAL RESEARCHERS (GALLOWAY AND COWLING 1978, LIKENS ET AL 1979, McFEE 1980) HAVE REPORTED THAT AREAS IN THE WESTERN PORTION OF THE UPPER PENINSULA OF MICHIGAN ARE SENSITIVE TO ACIDIC DEPOSITION. THE CURRENT MEAN ANNUAL pH OF PRECIPITATION IN THE UPPER PENINSULA RANGES FROM 4.3 IN THE EASTERN END TO 4.6 IN THE WESTERN END (BECKER ET AL 1982), VALUES WHICH ARE 20 AND 10 TIMES MORE ACIDIC THAN "NORMAL" PRECIPITATION OF pH 5.6 RESPECTIVELY. DOHRENWEND ET AL (1980) REPORTED SNOWFALL pH VALUES AS LOW AS 3.9 IN THE KEWEENAW PENINSULA IN MARCH 1978. CLEARLY, THERE ARE AREAS OF THE STATE WHERE ACIDIC DEPOSITION COULD HAVE SERIOUS EFFECTS.

IN FACT, THE LEGISLATIVE OFFICE OF THE SCIENCE ADVISOR OF THE STATE OF MICHIGAN (DEHRING AND HOLTGREIVE 1982) HAS RECOGNIZED THAT "ACID RAIN IS A PROBLEM CONTINUOUSLY GROWING IN SERIOUSNESS IN MICHIGAN..." IT HAS BEEN ESTIMATED THAT THE WESTERN PORTION OF THE UPPER PENINSULA OF MICHIGAN HAS SOME 8000 LAKES AND PONDS (U.S.-CANADA MEMORANDUM OF INTENT 1981). IN A RECENT SURVEY OF 90 LAKES AND STREAMS IN UPPER MICHIGAN (INCLUDING A FEW IN ONTARIO), LOUCKS ET AL (1983) REPORTED THAT 12% WERE ACIDIFIED (ALKALINITY LESS THAN 0) AND A TOTAL OF 58%

~~WERE SENSITIVE TO ACIDIFICATION HAVING ALKALINITY VALUES~~

~~1. THE EFFECTS OF ACIDIFICATION ON~~  
THE AQUATIC BIOTA ARE CURRENTLY BEING ASSESSED (HOKANSON ET AL 1983). BURTON ET AL (1981A, 1981B) HAVE ADDRESSED THE EFFECTS OF ACIDIFICATION IN MICHIGAN STREAMS IN WORK USING ARTIFICIAL STREAM CHANNELS SIMULATING ACTUAL STREAM CHEMISTRY.

#### 5.4 AQUATIC EFFECTS IN ONTARIO

MANY LAKES NEAR SUDBURY, ONTARIO HAVE BEEN ACIDIFIED BY ATMOSPHERIC DEPOSITION OF ACIDS (BEAMISH AND HARVEY 1972, CONROY ET AL 1975). THE PROBLEM WAS REGARDED AS A LOCAL ONE DUE TO EMISSIONS OF  $SO_2$  FROM COPPER AND NICKEL SMELTERS IN THE SUDBURY AREA AND WAS ADDRESSED BY REDUCING EMISSIONS AND COMMISSIONING THE WORLD'S TALLEST STACK IN 1972. THE EMISSIONS FROM THESE SOURCES ARE ONLY A PORTION OF THE TOTAL EMISSIONS TO THE ATMOSPHERE LEADING TO ACIDIC DEPOSITION IN ONTARIO. THE FACT THAT

THE EMISSIONS FROM SUDBURY WERE NOT THE ONLY CAUSE OF ACIDIC DEPOSITION IN ONTARIO WAS DRAMATICALLY DEMONSTRATED WHEN ACIDIC DEPOSITION CONTINUED IN MUSKOKA-HALIBURTON DURING THE SHUTDOWN (BY STRIKE) OF INCO LIMITED IN 1978-79 (SCHEIDER ET AL 1981). THE AQUATIC EFFECTS DOCUMENTED IN THIS SECTION ARE NOT THE RESULT OF EMISSIONS SOLELY FROM SUDBURY.

THE EFFECTS OF LONG RANGE TRANSPORT OF ACIDIC MATERIALS ON AQUATIC SYSTEMS IN ONTARIO ARE BEING RESEARCHED AT SEVERAL STUDY SITES. IN GENERAL, THE PROJECTS ONGOING AT THE SITES INVOLVE HIGHLY DETAILED WORK ON A SMALL NUMBER OF LAKES/WATERSHEDS (CALIBRATED WATERSHEDS) AND LESS INTENSIVE WORK ON A LARGER STUDY SET. THIS GENERAL APPROACH IS BEING USED ACROSS EASTERN NORTH AMERICA (FIGURE 5.1). IN ONTARIO, THE THREE PRINCIPAL SITES ARE THE EXPERIMENTAL LAKES AREA NEAR KENORA, THE TURKEY LAKES PROJECT IN ALGOMA NEAR SAULT STE MARIE AND THE DORSET RESEARCH CENTRE IN MUSKOKA-HALIBURTON. THESE THREE SITES ARE REPRESENTATIVE OF THE ACID SENSITIVE AREAS OF ONTARIO (U.S.-CANADA MEMORANDUM OF INTENT 1983).

#### 5.4.1 EFFECTS ON WATER QUALITY

TO ASCERTAIN THE SENSITIVITY OF LAKES TO ACIDIFICATION ACROSS ~~ONTARIO~~, SOME ~~40 LAKES~~ ~~WATERSHEDS~~ ~~WERE~~ ~~SURVEYED~~ (MINISTRY OF ENVIRONMENT 1983) FOR ALKALINITY IN AN ONGOING PROGRAM (TABLE 5.1). ~~ABOUT 4% OF THE LAKES~~ ~~SURVEYED ARE ACIDIFIED~~ ~~ALKALINITY~~

13% OF THE LAKES WERE [REDACTED]  
[REDACTED]  
THESE DATA [REDACTED] AND  
[REDACTED] TO BE ACIDIFIED, IE. CURRENT  
LEVELS [REDACTED]. FURTHERMORE, [REDACTED]  
OF THE LAKES [REDACTED] LESS  
[REDACTED]  
SENSITIVITY IN TOTAL, [REDACTED]  
[REDACTED] ACIDIFICATION.

HISTORICAL EVIDENCE OF LAKE ACIDIFICATION IN ONTARIO IS DIFFICULT TO OBTAIN BECAUSE OF THE LIMITED AMOUNT OF BASELINE DATA. HOWEVER, ONE WELL-DOCUMENTED CASE IS THAT OF CLEAR LAKE IN MUSKOKA-HALIBURTON. THE SUMMER ALKALINITY VALUE OF [REDACTED] WAS 33 UEQ L<sup>-1</sup> IN 1967 (SCHINDLER AND NIGHSWANDER 1970) AND VARIED BETWEEN 2 TO 15 UEQ L<sup>-1</sup> WHEN RESAMPLED IN 1977 (DILLON ET AL 1978). THIS INDICATES A LOSS OF BUFFERING CAPACITY OF AT LEAST 50% IN THAT 10 YEAR PERIOD. THE LAKE IS UNIQUE ONLY IN THAT ACCURATE HISTORICAL DATA ARE AVAILABLE.

DETRIMENTAL WATER QUALITY EFFECTS ARE ALSO BEING OBSERVED ON A SHORT-TERM OR EPISODIC BASIS. JEFFRIES ET AL (1979) COMPARED pH VALUES OF A SERIES OF SMALL STREAMS IN THE MUSKOKA-HALIBURTON STUDY AREA, BEFORE AND DURING SPRING RUNOFF. THE pH DECLINES OF THE LAKE OUTFLOWS DEMONSTRATED THAT THE TOP PORTIONS OF THE ENTIRE LAKES

WERE ACIDIFIED. THE LOWEST STREAM pH VALUES OBSERVED, 4.1 TO 5.1 (TABLE 5.2), WERE WITHIN A RANGE CAPABLE OF CAUSING DAMAGE TO SOME AQUATIC ORGANISMS, PARTICULARLY FISH. AS MUCH AS 77% OF THE MEASURED ANNUAL ACID EXPORT OF THE STREAMS OCCURRED IN APRIL. ~~A SYSTEMATIC GRAPH AND pH RESPONSE FOR ONE OF THE STREAMS DURING THE SNOWMELT PERIOD IS SHOWN IN FIGURE 5.2.~~

SIMILARLY, KELLER (1983) NOTED REDUCTIONS IN pH AND ALKALINITY IN 21 TRIBUTARIES TO THE ALGOMA AREA OF LAKE SUPERIOR DURING THE SPRING RUNOFF OF 1981:

THE pH OF STREAMS IN MUSKOKA-HALIBURTON WAS DEPRESSED FOR PERIODS OF AS LITTLE AS A FEW HOURS DURING TIMES OF HEAVY RUNOFF IN THE SUMMER MONTHS (FIGURE 5.3; SCHEIDER ET AL 1979B). ~~HEAVY RAINFALL IN THE SUMMER MONTHS OF 1979 CAUSED A DEPRESSION IN pH FOR DAYS AT A TIME.~~ JEFFRIES ET AL (1979) OBSERVED AS MUCH AS 26% OF THE TOTAL ANNUAL HYDROGEN ION RUNOFF IN OCTOBER.

AS PREVIOUSLY NOTED, THE ASSIMILATION OF ACIDIC DEPOSITION BY TERRESTRIAL WATERSHEDS MAY MOBILIZE AL, FE AND MN. ALUMINUM IS THE MOST IMPORTANT OF THESE BECAUSE OF ITS TOXIC EFFECTS ON AQUATIC BIOTA. SCHEIDER ET AL (1979B) REPORTED AN AVERAGE TOTAL AL CONCENTRATION OF ~~1.1-1.4 mg/L FOR 14 DORSET STUDY LAKES.~~ AL CONCENTRATIONS IN ~~STREAMS ARE~~ WITH SOME

VALUES EXCEEDING 500 UG L<sup>-1</sup> DURING SPRING RUNOFF (LAZERTE  
1983).

SIMILARLY, KELSO ET AL (1982) REPORTED A MEAN OF [REDACTED]  
[REDACTED] [REDACTED] [REDACTED] [REDACTED] [REDACTED] [REDACTED]  
[REDACTED] [REDACTED] [REDACTED] [REDACTED] [REDACTED] [REDACTED]  
NON-VOLATILE AMBIENT WATER TAKES IN ONTARIO ARE  
APPROXIMATELY 3 MG L<sup>-1</sup> (DRISCOLL ET AL 1980). pH AND AL  
LEVELS IN DORSET LAKES AND STREAMS DURING SPRING MELT CAN  
FALL WITHIN THE RANGES WHICH LABORATORY EXPERIMENTS  
(DRISCOLL ET AL 1980) HAVE SHOWN TO BE LETHAL TO FISH.

#### 5.4.2 EFFECTS ON AQUATIC BIOTA

ALTHOUGH WATER QUALITY CHANGES ARE A CONCERN IN THEIR OWN RIGHT, IT IS THE BIOLOGICAL RESPONSES TO ACIDIFICATION WHICH ARE OF UPPERMOST IMPORTANCE. DAMAGE TO FISH POPULATIONS IS A MAJOR CONCERN SINCE IT REPRESENTS A LOSS TO THE SPORT FISHING INDUSTRY AS WELL AS A DISRUPTION IN THE BIOLOGICAL FOOD CHAIN. COMPLETE LOSS OF FISH TENDS TO BE REGARDED AS THE DEFINITION OF A "DEAD" LAKE.

THE REPORTED EFFECTS OF ACIDIFICATION ON FISH IN ONTARIO  
ARE MANY AND VARIED. HARVEY (1979) REPORTED FISH KILLS  
IN PLASTIC LAKE IN HALIBURTON DURING THE SPRING MELT WHEN  
THE SURFACE WATER PH OF THE LAKE WAS 5.5 AND THE MAJOR  
INLET STREAM HAD A PH OF 4.5. TOTAL AL LEVELS  
RANGED BETWEEN 9 TO 30 MG/L IN THE LAKE AND 300 TO 400  
MG/L IN THE STREAM DURING THE 1979-80 OPEN WATER  
SEASON. FISH CAGING EXPERIMENTS IN THE SPRING OF 1981

(HARVEY 1981) CONFIRMED THE TOXIC NATURE OF THE WATER, PARTICULARLY THE INLET STREAM (pH 4.0 TO 4.1) WHERE 100% OF CAGED FISH DIED IN TWO DAYS. SHORTLY AFTER THE CAGING EXPERIMENT, SCUBA DIVERS OBSERVED DEAD FISH IN THE LAKE AS WELL.

LOSS OF FISH POPULATIONS HAS BEEN DOCUMENTED FOR SEVERAL LAKES IN ONTARIO CONCURRENT WITH LAKE ACIDIFICATION (HARVEY AND LEE 1982). ONE MECHANISM OF EXTINCTION IS

~~AS OBSERVED AT PATTEN LAKE IN THE LA CLOCHE MOUNTAINS (FIGURE 5.4) (RYAN AND HARVEY 1980). ABSENCE OF OLDER FISH FROM THE POPULATION IN ACID-STRESSED LAKES HAS ALSO BEEN OBSERVED. FIGURE 5.5 ILLUSTRATES THE AGE DISTRIBUTION OF WHITE SUCKERS (CATOSTOMUS COMMERSONI) IN GEORGE LAKE NEAR SUDBURY DURING A 13 YEAR PERIOD WHILE THE LAKE WAS BECOMING ACIDIC (BEAMISH 1970, BEAMISH 1976, BEAMISH ET AL 1975, HARVEY 1980B). FIGURES 5.6 AND 5.7 SHOW AGE DISTRIBUTIONS OF WHITE SUCKER IN CROSSON, RED CHALK AND HARP LAKES IN MUSKOKA-HALIBURTON (HARVEY 1980B). THE ACID-STRESSED CROSSON LAKE (pH 5.4 TO 6.4) HAS AN AGE DISTRIBUTION SIMILAR TO GEORGE LAKE SHOWING THE SHIFT TO YOUNGER AGE CLASSES COMPARED TO THE NEAR-NEUTRAL RED CHALK LAKE (pH 5.5 TO 7.2) AND HARP LAKE (pH 5.8 TO 7.0).~~

~~SPECIES~~  
~~PRESENT IN THE LAKE~~  
~~ENVIRONMENTAL~~

WHILE ONLY AL IN ACIDIC WATERS HAS BEEN LINKED TO FISH KILLS, SEVERAL OTHER METALS ARE ELEVATED IN FISH TISSUES IN ACID-STRESSED LAKES WHERE THEY MAY IMPAIR THE HEALTH OF THE FISH OR IMPOSE A DANGER TO THE ULTIMATE CONSUMER OF THE FISH. SUNS ET AL (1980) FOUND INCREASED MERCURY CONCENTRATIONS IN YEARLING YELLOW PERCH (PERCA FLAVESCENS) TO BE CORRELATED WITH DECREASING LAKE pH IN MUSKOKA-HALIBURTON (FIGURE 5.8). SIMILARLY, INCREASED LEAD AND CADMIUM RESIDUES IN YEARLING YELLOW PERCH WERE RELATED TO LAKE pH IN MUSKOKA-HALIBURTON (SUNS 1982). FRASER AND HARVEY (1982) FOUND THAT MN RESIDUES IN WHITE SUCKER BONES INCREASED IN ACID-STRESSED LAKES COMPARED TO LAKES WITH NEAR-NEUTRAL pH VALUES IN MUSKOKA-HALIBURTON.

IN THE MUSKOKA-HALIBURTON AREA, ~~DETERMINED THAT THE~~  
~~SPECIES OF AMPHIBIANS DECREASE WITH INCREASING ACIDITY IN~~  
~~THE MUSKOKA-HALIBURTON AREA~~. ACIDIC LAKES AND STREAMS SUPPORT A SMALLER BREEDING POPULATION OF SPRING PEEPER (HYLA CRUCIFER) THAN MORE NEUTRAL HABITATS. DECIDUOUS WOODLAND PONDS ARE THE TYPICAL BREEDING HABITATS FOR AMBYSTOMA ~~SALICINUM~~ HOWEVER, SUCH PONDS HAVE BEEN OBSERVED IN MUSKOKA-HALIBURTON TO BE VERY ACIDIC WITH pH'S AS LOW AS 4.3. THESE ACIDIC PONDS ARE NOW SELDOM USED AS BREEDING SITES AND THUS REPRESENT A LOSS OF HABITAT FOR THIS SPECIES. THE HATCHING SUCCESS OF ANY EGGS LAID IN THESE HABITATS IS LOW (CLARK AND EULER 1981).

ALTHOUGH RELATIVELY LITTLE WORK HAS BEEN DONE TO DATE ON THE EFFECTS OF ACIDIFICATION ON AQUATIC MACROINVERTEBRATES IN ONTARIO, NUMEROUS AQUATIC INSECTS ARE KNOWN TO BE AFFECTED BY ACIDIFICATION AND THEIR DISTRIBUTION HAS BEEN RELATED TO THE pH OF LAKES AND RIVERS (REVIEWED BY HARVEY ET AL 1981 AND DILLON ET AL 1983). FROM THESE STUDIES, IT APPEARS THAT ~~mayflies~~ AND ~~amphipods~~ ARE USUALLY SPARSELY DISTRIBUTED IN ACIDIC WATERS. ~~snails and clams~~ (SNAILS AND CLAMS) AND ~~crustaceans~~ ARE VERY SENSITIVE TO LOW pH WATERS.

THE ACIDIFICATION OF LAKES IN ONTARIO IS ACCOMPANIED BY CHANGES IN THE OCCURRENCE AND ABUNDANCE OF ZOOPLANKTON AND REDUCTIONS IN THE DIVERSITY AND BIOMASS OF ZOOPLANKTON COMMUNITIES (REVIEWED BY HARVEY ET AL 1981 AND DILLON ET AL 1983).

BOTH THESE TINY ANIMAL FORMS AND THE AQUATIC MACROINVERTEBRATES (INSECTS, CLAMS, SNAILS, ETC.) FORM IMPORTANT LINKS IN THE AQUATIC FOOD CHAIN CAPPED BY THE TOP PREDATORS, FISH.

THE DECLINE OF MACROPHYTE PLANT SPECIES AND THE CONCURRENT INVASION OF SPHAGNUM MOSS REPORTED IN ACIDIFIED LAKES IN SCANDINAVIA AND THE ADIRONDACKS (REVIEWED BY HARVEY ET AL 1981 AND DILLON ET AL 1983) HAVE NOT YET BEEN RECORDED IN ONTARIO LAKES. SPHAGNUM

MOSS COVERAGE OF THE NEARSHORE AREAS OF LAKES CREATES A HABITAT UNSUITABLE FOR USE AS FISH SPAWNING AND FEEDING GROUNDS.

ALGAL COMMUNITY COMPOSITION AND ABUNDANCE ARE ALTERED IN ACIDIC AND ACID-STRESSED LAKES. THESE CHANGES CAN BE DETRIMENTAL TO THE RECREATIONAL USE OF THE LAKES AND POSE A THREAT TO THE HABITAT OF SOME AQUATIC ORGANISMS. FOR EXAMPLE, LAKES WITH REDUCED pH SUPPORT A PROLIFERATION OF ALGAE (~~BRACHYDONTOMUS NA BREVIPURUS~~) ATTACHED TO THE BOTTOM (STOKES 1981). THESE ALGAE CAN ~~CAUSE DETRIMENTAL EFFECTS~~ ~~ON THE HABITAT~~ SIGNIFICANT GROWTHS OF THESE ALGAE HAVE BEEN OBSERVED IN MUSKOKA-HALIBURTON LAKES SUCH AS ~~LAKE~~ AND ~~LAKE~~

ANOTHER OBSERVED CHANGE, DETRIMENTAL TO RECREATIONAL ACTIVITIES, IS THE APPEARANCE OF AN ALGA CALLED ~~BRACHYDONTOMUS NA BREVIPURUS~~ NICH. WHICH IS CHARACTERIZED BY A SEVERE "ROTTEN CABBAGE" OR "~~CABBAGE~~ ~~ODOUR~~" WHICH HAS CAUSED LAKES TO BE UNSUITABLE FOR SWIMMING. IN RECENT YEARS, THIS ALGA HAS REACHED PROBLEM CONCENTRATIONS IN FOUR LAKES IN ONTARIO AND ONE IN NEW HAMPSHIRE. ~~LAKE~~ LAKE HAS EXPERIENCED THE PROBLEM. ~~LAKE~~ LAKE HAD AN EXTREME PROBLEM IN 1979, AND COTTAGERS THERE FOR OVER 20 YEARS MADE NO PREVIOUS OBSERVATIONS OF THE ODOUR (NICHOLLS ET AL 1981). THE ODOUR IS SO BAD THAT RESIDENTS WOULD LIKELY HAVE REMEMBERED HAD IT EVER

OCCURRED BEFORE. THE ALGA HAS BEEN IDENTIFIED NOW AT VARIOUS POPULATION SIZES (DENSITIES) IN OVER 40 LAKES IN ONTARIO, MOST OF WHICH HAVE LOW pH (NICHOLLS ET AL 1981).

ALTHOUGH LITTLE INFORMATION HAS BEEN COLLECTED ON THE ROLE OF MICROORGANISMS IN ACID-STRESSED SYSTEMS, STUDIES HAVE SHOWN THAT ~~\_\_\_\_\_~~

~~\_\_\_\_\_~~ (REVIEWED BY HARVEY ET AL 1981 AND DILLON ET AL 1983). IT IS BELIEVED THAT SUCH DISRUPTIONS WILL AFFECT THE NUTRIENT CYCLING AND HENCE OTHER TROPHIC LEVELS IN ACIDIFIED SURFACE WATERS.

#### 5.5 ~~\_\_\_\_\_~~

LEVELS OF ACIDIC DEPOSITION ARE ELEVATED OVER "BACKGROUND" VALUES ACROSS MOST OF THE SENSITIVE PRECAMBRIAN AREAS OF ONTARIO, ESPECIALLY IN THE RECREATIONAL AREA OF MUSKOKA-HALIBURTON. OF THE 4016 LAKES SURVEYED ACROSS ONTARIO TO DATE, 4% ARE ACIDIC AND 13% ARE EXTREMELY SENSITIVE. IN TOTAL, 72% OF THE LAKES SURVEYED SHOW SOME SENSITIVITY TO ACIDIC DEPOSITION.

HISTORICAL EVIDENCE OF ACIDIFICATION IS DOCUMENTED FOR CLEAR LAKE, IN HALIBURTON. THE ALKALINITY OF THE LAKE HAS DECLINED BY 50% OVER THE PAST 10 YEARS. THIS LAKE IS UNIQUE ONLY IN THAT HISTORICAL DATA EXISTS FOR IT. SOME 33% OF LAKES SURVEYED IN HALIBURTON HAVE ALKALINITIES IN THE SAME RANGE AS CLEAR LAKE.

EPISODIC pH DEPRESSIONS IN LAKES AND RIVERS DURING SPRING SNOWMELT AND RUNOFF HAVE BEEN OBSERVED IN ALGOMA AND MUSKOKA-HALIBURTON. SHORT-TERM pH DEPRESSIONS HAVE ALSO BEEN OBSERVED FOLLOWING HEAVY SUMMER AND AUTUMN RAINS. ALUMINUM LEVELS IN SOME STREAMS ARE IN THE RANGE OF VALUES KNOWN TO BE LETHAL TO FISH FROM LABORATORY STUDIES.

INTENSIVE STUDIES ON THE BIOLOGICAL EFFECTS OF ACIDIFICATION ARE BEING CARRIED OUT IN A SMALL NUMBER OF LAKES. FISH KILLS HAVE BEEN OBSERVED IN ONE LAKE. COMPLETE LOSSES OF FISH POPULATIONS CONCOMITANT WITH LAKE ACIDIFICATION ARE KNOWN FOR SEVERAL LAKES, THE MECHANISM LIKELY RECRUITMENT FAILURE. REDUCTION IN THE ABUNDANCE OF CERTAIN AGE CLASSES OF FISH IS KNOWN FOR OTHER ACID-STRESSED LAKES. INCREASED LEVELS OF MERCURY, LEAD, CADMIUM AND MANGANESE HAVE BEEN NOTED IN TISSUES OF FISH FROM LOW pH LAKES. ANY LOSS OR MODIFICATION OF THE QUALITY OF SPORT FISH IS A MAJOR CONCERN TO THE SPORT FISHING INDUSTRY VALUED AT HUNDREDS OF MILLIONS OF DOLLARS PER YEAR IN ONTARIO.

THE POTENTIAL FOR OTHER BIOLOGICAL EFFECTS HAS ALSO BEEN SHOWN AND IN MANY CASES DAMAGE HAS BEEN DOCUMENTED BY FIELD OBSERVATIONS. OBSERVED EFFECTS ON BIOTA IN ACIDIFIED SYSTEMS INCLUDE A DECLINE IN THE BREEDING POPULATION OF CERTAIN AMPHIBIANS, REDUCED NUMBERS OF ZOOPLANKTON AND BENTHIC MACROINVERTEBRATES, CHANGES IN ALGAL COMMUNITIES, THE OCCURRENCE OF A FOUL SMELLING ALGA

THAT RESTRICTS RECREATIONAL USE OF THE LAKE AND DECREASED MICROBIAL DECOMPOSITION RATES WITH POTENTIAL EFFECTS ON LAKE TROPHIC STATUS.

THE ACID-STRESSED LAKES UNDER STUDY ARE SHOWING MANY INSTANCES OF BIOLOGICAL DAMAGE. IT IS HIGHLY LIKELY THAT SIMILAR DAMAGE IS OCCURRING IN THE THOUSANDS OF SIMILARLY ACID-STRESSED LAKES IN ONTARIO.



Figure 5.1 Regions of North America containing lakes that are sensitive to acidification by acid precipitation, based on bedrock geology, showing where calibrated watershed studies on sensitive areas are in progress.

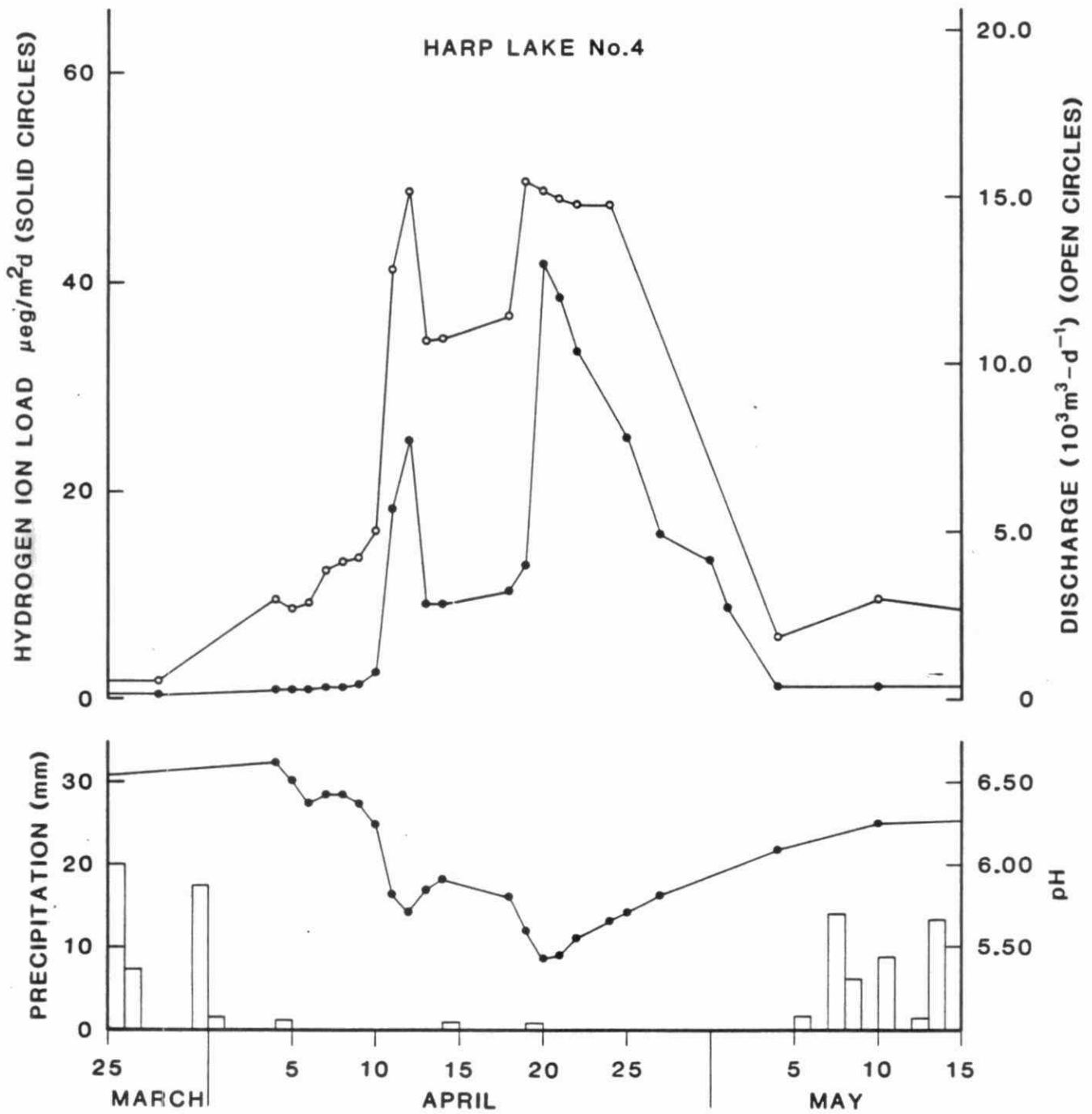


Figure 5.2 "Spring pH Depression" of a Stream  
Graph illustrating "spring pH depression" in one of the six inflowing streams to Harp Lake, a study lake in Muskoka. (Jeffries et al 1979)

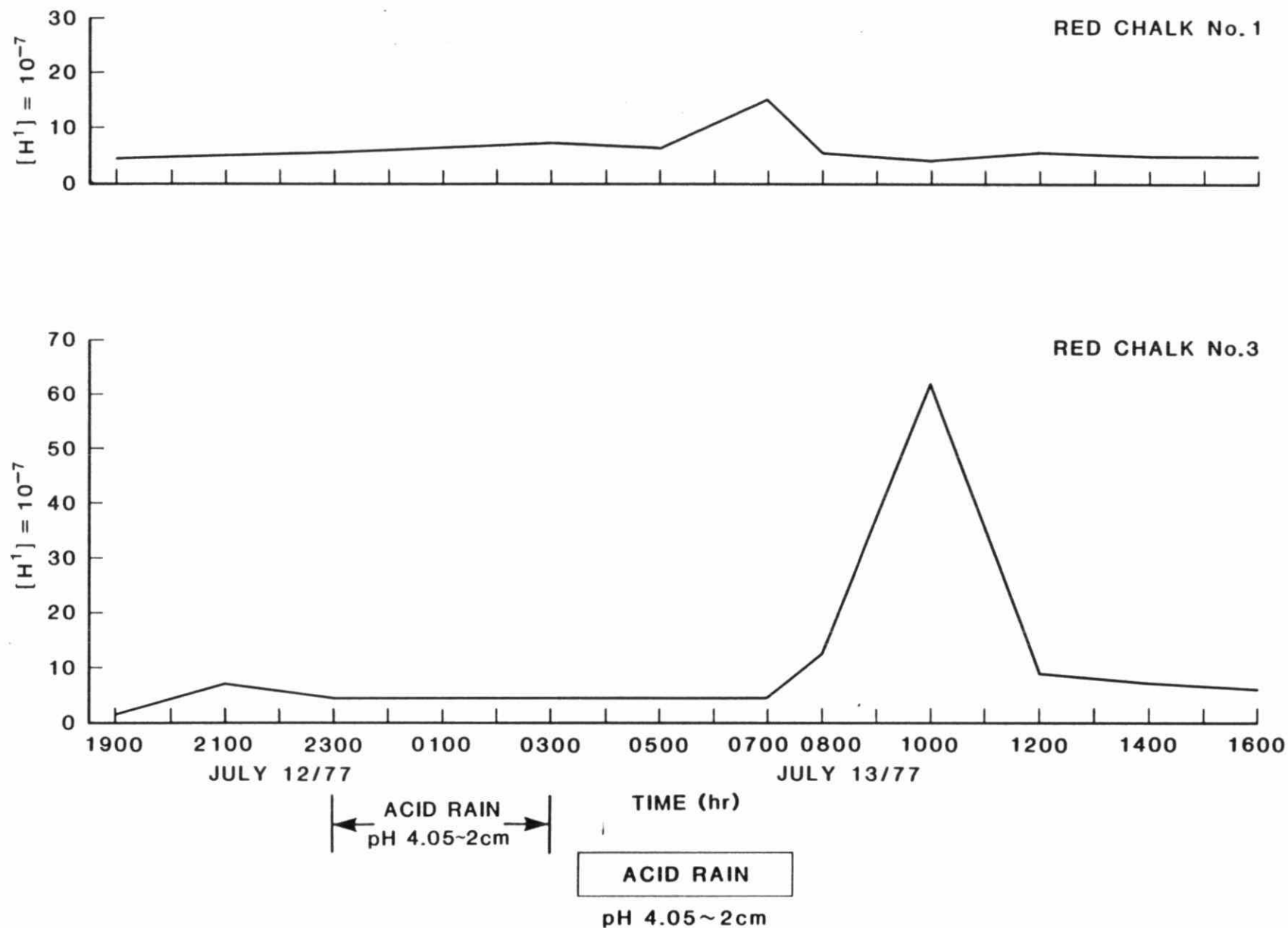


Figure 5.3 Hydrogen ion content of streams draining Red Chalk Lake watersheds No. 3 and No. 1 (Dorset, Ontario) showing effects of a 2cm rainfall (pH 4.06) between 11:00p.m. July 12, 1977 and 3:00a.m. July 13, 1977. (Scheider et al 1979b)

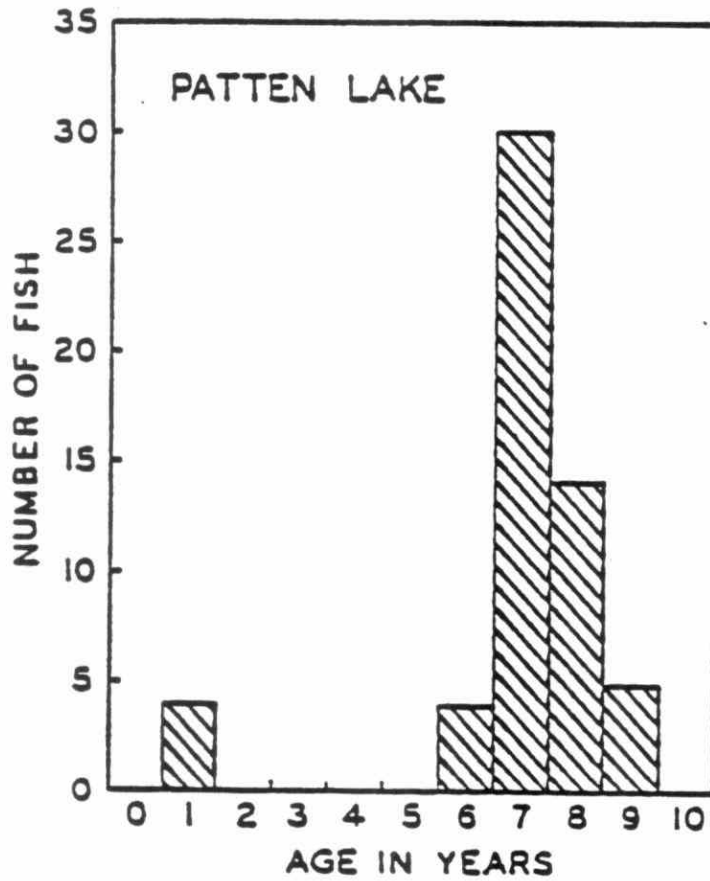


Figure 5.4 Age composition of yellow perch (*Perca flavescens*) captured in Patten Lake, Ontario, pH 4.1. (Ryan and Harvey 1980)

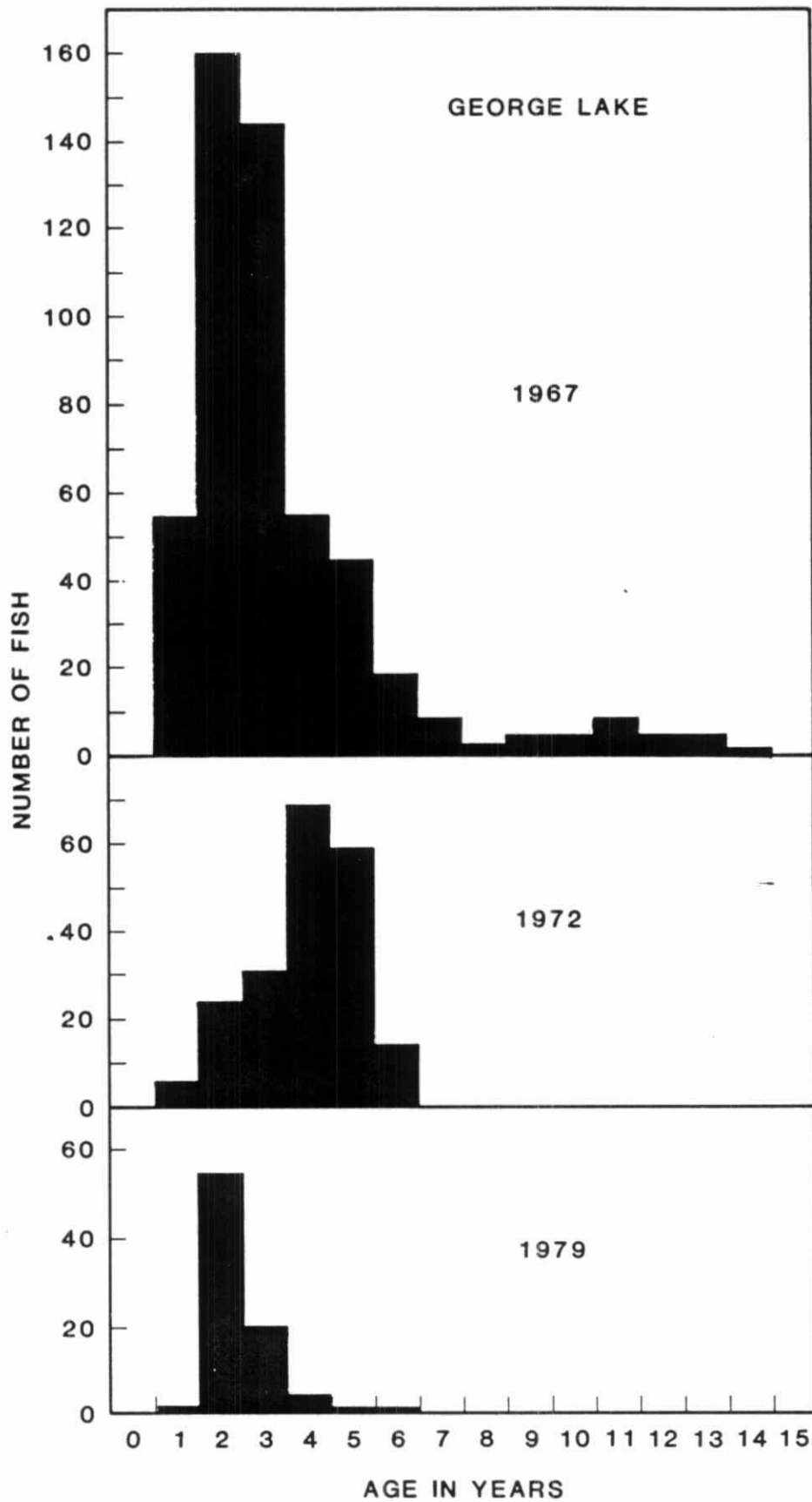


Figure 5.5 Changes in the age composition of the white sucker (*Catostomus commersoni*) population in George Lake, Ontario. (Harvey 1980b)

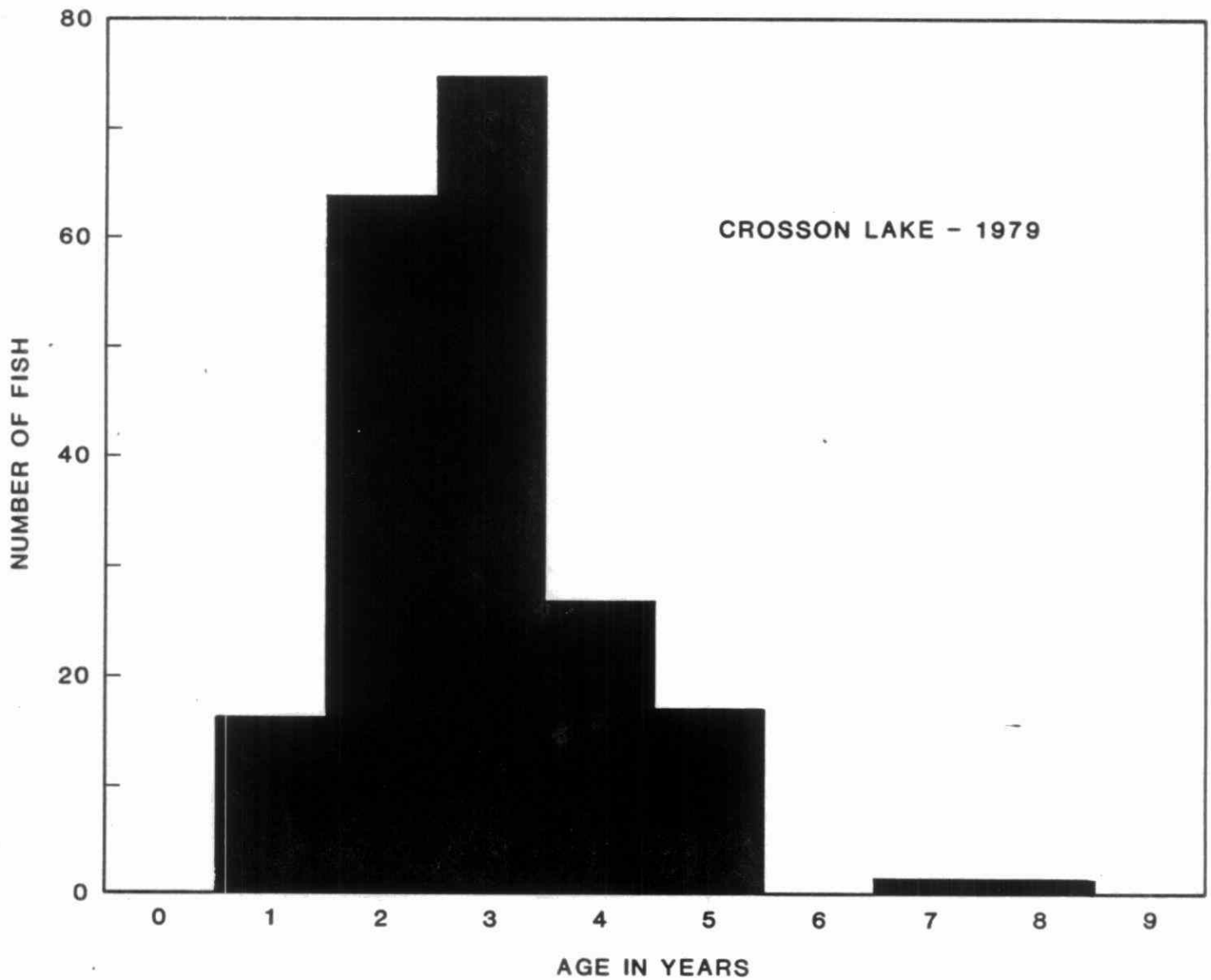


Figure 5.6 Age composition of the white sucker (Catostomus commersoni) population in Crosson Lake. (Harvey 1980b)

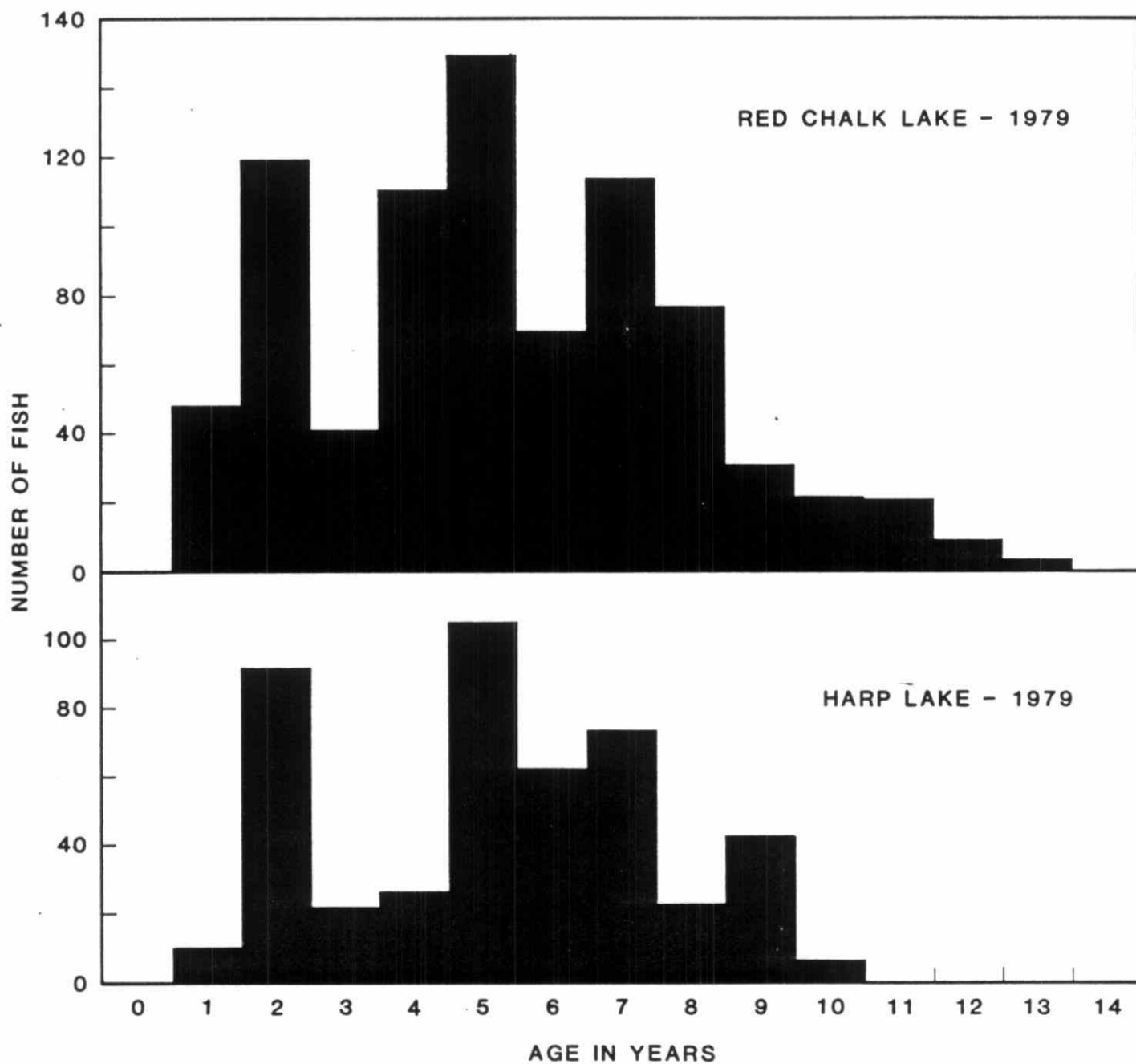
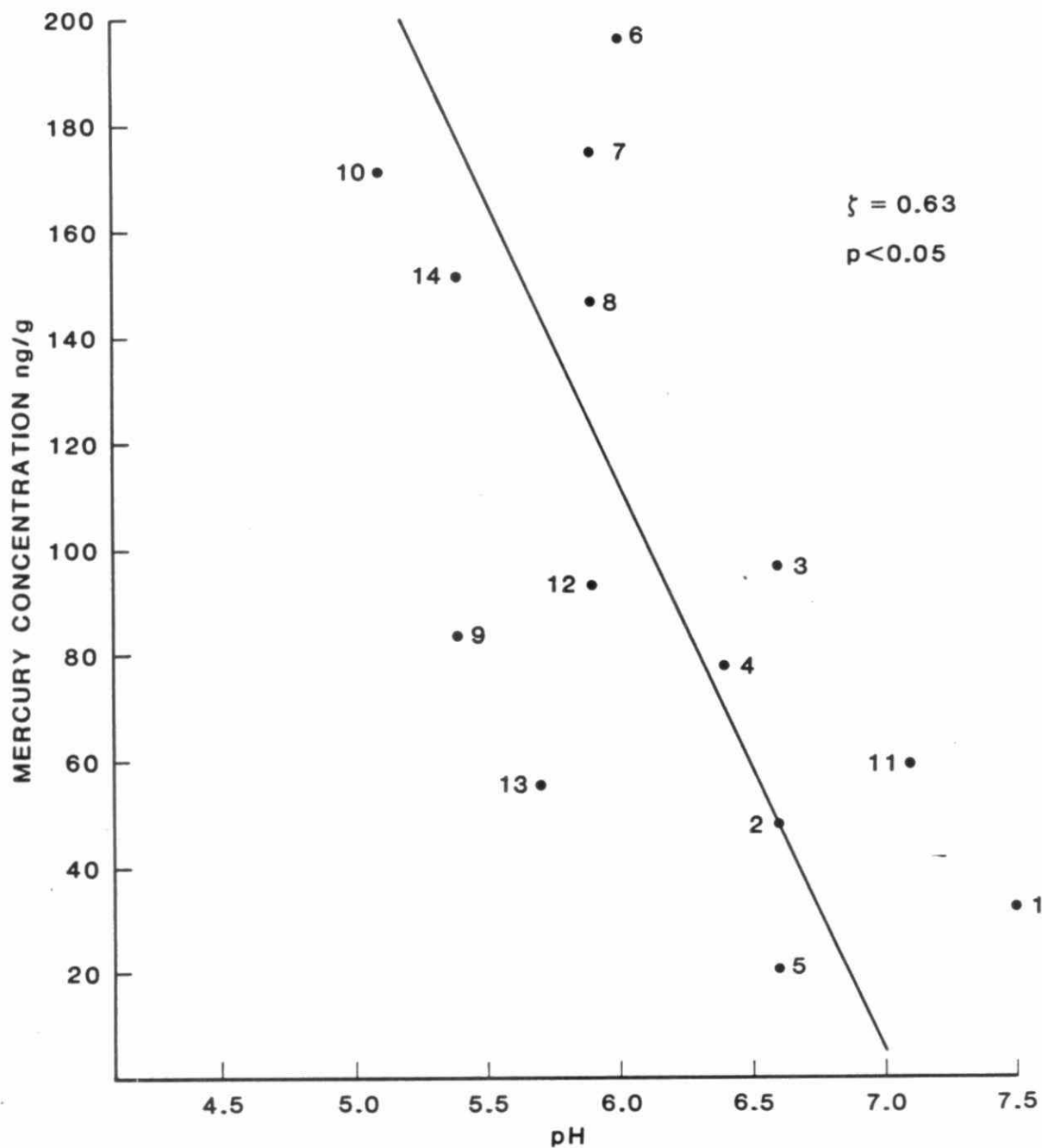


Figure 5.7 Age composition of the white sucker (*Catostomus commersoni*) populations for Harp and Red Chalk Lakes, 1979. (Harvey 1980b)



1978 DATA

LAKE #, NAME	TWP.	LAKE #, NAME	TWP.
1 DUCK LAKE	MINDEN	8 DICKIE LAKE	McLEAN
2 LITTLE CLEAR LAKE	SINCLAIR	9 LEONARD LAKE	MONCK
3 HARP LAKE	SINCLAIR	10 HENEY LAKE	McLEAN
4 BIGWIND LAKE	OAKLEY	11 CRANBERRY LAKE	GUILFORD
5 NELSON LAKE	BOWELL	12 HEALEY LAKE	McCAULEY
6 CHUB LAKE	RIDOUT	13 CLEAR LAKE	STANHOPE
7 CROSSON LAKE	OAKLEY	14 FAWN LAKE	McCAULEY

Figure 5.8 Mercury concentrations in yearling yellow perch (*Perca flavescens*) and epilimnetic pH relationships. (Suns et al 1980)

TABLE 5.1: SUMMARY OF THE PERCENTAGE OF LAKES IN EACH ALKALINITY CLASS BY COUNTY OR DISTRICT AND FOR ONTARIO. (MINISTRY OF THE ENVIRONMENT 1983)

County or District	Percentage of Total Number of each Alkalinity Class					Total No. of Lakes Evaluated
	Acidified ( 0 ueq L <sup>-1</sup> )	Extreme Sensitivity ( 0 to 39.9 ueq L <sup>-1</sup> )	Moderate Sensitivity (40 to 199 ueq L <sup>-1</sup> )	Low Sensitivity (200 to 499 ueq L <sup>-1</sup> )	Not Sensitive ( 500 ueq L <sup>-1</sup> )	
Algoma Dist.	4.2	13.1	45.2	20.2	17.3	451
Bruce Co.	.	.	.	.	100.0	7
Cochrane Dist.	0.9	2.9	5.8	12.5	77.9	104
Durham Co.	.	.	.	.	100.0	1
Frontenac Co.	.	.	1.4	13.5	85.1	74
Grey Co.	.	.	.	.	100.0	3
Haliburton Co.	1.9	33.3	43.8	12.0	8.9	258
Hastings Co.	.	.	33.3	19.0	47.6	105
Huron Co.	.	.	.	.	100.0	1
Kenora Dist.	.	0.4	30.0	33.0	36.5	260
Lanark Co.	.	.	.	2.7	97.4	38
Leeds Co.	.	.	.	.	100.0	32
Lennox & Addington Co.	.	4.5	29.5	21.6	44.3	88
Manitoulin Dist.	42.6	42.6	2.1	2.1	10.6	47
Middlesex Co.	.	.	.	.	100.0	1
Muskoka Dist.	1.1	27.0	62.1	3.4	6.3	174
Nipissing Dist.	1.7	14.3	68.1	15.1	0.8	517
Northumberland Co.	.	.	.	.	100.0	1
Parry Sound Dist.	3.6	25.9	62.7	7.3	0.5	193
Peel Co.	.	.	.	.	100.0	1
Peterborough Co.	.	3.6	12.7	10.9	72.7	55
Prince Edward Co.	.	.	.	.	100.0	9
Rainy River Dist.	.	5.3	59.8	22.0	13.0	246
Renfrew Co.	0.9	8.3	48.6	25.5	16.6	337
Simcoe Co.	.	.	41.2	.	58.8	17
Stormont Co.	.	.	.	.	100.0	1
Sudbury Dist.	16.8	23.2	29.3	13.2	17.5	423
Thunder Bay Dist.	1.0	4.9	26.0	29.4	38.8	410
Timiskaming Dist.	11.3	13.7	21.8	25.0	28.2	124
Victoria Co.	.	.	61.8	2.9	35.3	34
York Co.	.	.	.	.	100.0	2
Provincial Total (number of lakes)	3.9 (155)	13.0 (522)	41.1 (1,649)	18.1 (725)	24.0 (965)	4,016

TABLE 5.2 pH OF STREAMS IN MUSKOKA-HALIBURTON, ONTARIO, CANADA: STREAM pH IS GIVEN PRIOR TO SPRING RUNOFF (MID-MARCH 1978) AND AT MAXIMUM RUNOFF (MID-APRIL 1978) (JEFFRIES ET AL 1979)

Watershed	Stream	pH	
		Mid-March	Mid-April
Harp Lake	3	6.1	5.1
	3A	6.0	5.6
	5	5.9	4.8
	6	6.2	5.3
	6A	5.4	5.0
	Outflow	6.3	5.0
Dickie Lake	5	4.6	4.3
	6	4.6	4.4
	11	4.9	4.1
	Outflow	5.6	4.9
Chub Lake	1	5.8	5.1
	2	5.2	4.7
	Outflow	5.5	4.8
Red Chalk Lake	1	6.1	5.6
	2	4.5	4.3
	3	6.0	5.5
	4	6.2	5.5
	Outflow	6.1	5.9
Maple Lake	Maple Creek	6.2	5.8
Lake Simcoe	Black River (at Vankoughnet)	6.3	5.9
Lake of Bays	Oxtongue River	6.3	6.1

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## 6. EFFECTS OF ACIDIC DEPOSITION ON TERRESTRIAL RESOURCES

### 6.1 INTRODUCTION

ACIDIC PRECIPITATION HAS THE POTENTIAL TO CAUSE SERIOUS WIDESPREAD EFFECTS ON TERRESTRIAL ECOSYSTEMS IN CERTAIN AREAS OF THE WORLD. THESE AREAS WHICH ARE RECEIVING EXCESSIVE LOADINGS OF ACIDIC DEPOSITION INCLUDE EASTERN CANADA, NORTHEASTERN U.S.A., SWEDEN, NORWAY AND GERMANY.

THERE IS LESS DOCUMENTED EVIDENCE OF THE EFFECTS OF ACIDIC PRECIPITATION ON TERRESTRIAL RESOURCES THAN THERE IS ON AQUATIC SYSTEMS; HOWEVER, BASED ON OBSERVATIONS MADE BOTH IN THE FIELD AND IN THE LABORATORY, ACIDIC PRECIPITATION POSES A DEFINITE POTENTIAL THREAT TO SOILS, AGRICULTURE AND FORESTRY.

NOT ONLY CAN ACIDIC PRECIPITATION BE HARMFUL, BUT THE INTERACTION WITH OTHER POLLUTANTS, SUCH AS ATMOSPHERIC OZONE AND SULPHUR DIOXIDE, OR WITH DEPOSITED HEAVY METALS, SUCH AS CADMIUM, LEAD AND MERCURY, MAY HASTEN THE DETERIORATION OF TERRESTRIAL RESOURCES.

BECAUSE OF THE INCREASING REPORTS OF ADVERSE EFFECTS ON TERRESTRIAL RESOURCES, THE ONTARIO MINISTRY OF THE ENVIRONMENT, THROUGH ITS ACIDIC PRECIPITATION IN ONTARIO STUDY (A.P.I.O.S.), EMBARKED ON AN INTENSIVE PROGRAM OF STUDYING THE EFFECTS OF ACIDIC DEPOSITION ON SOILS, AGRICULTURAL CROPS AND FORESTRY IN 1980. AS A FOUNDATION FOR THESE STUDIES, THE MINISTRY PUBLISHED AN ANNOTATED

BIBLIOGRAPHY ON THE TERRESTRIAL EFFECTS OF ACIDIC  
PRECIPITATION (LINZON ET AL 1981A).

6.2 EFFECTS ON SOILS

IN EXPERIMENTS USING SIMULATED ACIDIC RAIN, A NUMBER OF ADVERSE EFFECTS HAVE BEEN PRODUCED IN SOILS. ALSO, FROM STUDIES CONDUCTED NEAR POINT SOURCES, FROM CHANGES OBSERVED IN SOIL CAUSED BY FERTILIZATION WITH NITROGEN-BEARING COMPOUNDS AND FROM CHANGES OCCURRING NATURALLY OVER LONG PERIODS OF TIME, A NUMBER OF EFFECTS CAN BE EXPECTED FROM SOIL ACIDIFICATION. THESE ADVERSE EFFECTS INCLUDE REDUCED pH, LEACHING OF BASIC CATIONS SUCH AS MAGNESIUM AND CALCIUM, REDUCTION IN BASE SATURATION AND CATION-EXCHANGE CAPACITY, MOBILIZATION OF SOIL-BOUND METALS SUCH AS ALUMINUM AND MANGANESE AND CHANGES IN BIOLOGICAL ACTIVITY (BACHE 1980).

WITH REGARD TO THE EFFECTS ON SOILS OBSERVED IN THE FIELD IN AREAS OF HIGH ACIDIC DEPOSITION, THE LEACHING OF BASIC CATIONS HAS BEEN DOCUMENTED BY CRONAN ET AL (1978). ALSO, THE INCREASED LEACHING OF ALUMINUM FROM SOILS TO GROUNDWATER AND THEN TO STREAMS AND LAKES HAS BEEN DOCUMENTED BY DICKSON (1978).

WIKLANDER (1974) DISCUSSED THE SENSITIVITY OF VARIOUS SOIL TYPES TO ACIDIC PRECIPITATION AND SUGGESTED THAT THERE WOULD BE NO EFFECTS ON CALCAREOUS SOILS WHICH HAVE A VERY HIGH BUFFERING CAPACITY, WHILE ACIDIFIED SOILS WITH A pH BELOW 5.0 WOULD BE ONLY SLIGHTLY AFFECTED SINCE

MOST OF THE CATION EXCHANGE SITES ARE ALREADY OCCUPIED BY H IONS. HE CONSIDERED THE MOST SENSITIVE SOIL TO ACIDIC PRECIPITATION TO BE A NON-CALCAREOUS SANDY SOIL WITH A pH OVER 6.0.

IN THE PROVINCE OF ONTARIO, AN OPPORTUNITY EXISTED TO TEST THESE VARIOUS THEORIES AS TO SENSITIVITY OF DIFFERENT SOIL TYPES TO ACIDIC PRECIPITATION. SOIL SURVEYS HAD BEEN CONDUCTED IN THE PAST IN VARIOUS PARTS OF ONTARIO IN WHICH A NUMBER OF PHYSICAL AND CHEMICAL CHARACTERISTICS HAD BEEN MEASURED IN DIFFERENT HORIZONS OF VARIOUS SOIL SERIES PROFILES.

THE 1960 SOIL SURVEY OF THE PARRY SOUND DISTRICT WAS SELECTED (HOFFMAN ET AL 1962) AND A RE-SURVEY WAS CONDUCTED IN 1978 TO SAMPLE SOIL PROFILES AND COLLECT DATA ON pH OF DIFFERENT SOIL TYPES. THIS PRELIMINARY WORK ON pH WAS FOLLOWED UP BY MORE DETAILED EXAMINATIONS OF OTHER SOIL PARAMETERS SUCH AS MECHANICAL ANALYSES (% SAND, % SILT, % CLAY), CATION EXCHANGE CAPACITY, % ORGANIC MATTER AND CONCENTRATIONS OF EXCHANGEABLE BASES (CA, MG, K), METALS (AL, FE) AND OTHER ELEMENTS. IN MOST CASES, pH DATA WERE ABOUT THE SAME FOR BOTH YEARS, 1960 AND 1978, AND DIFFERENCES MAY BE PARTLY ATTRIBUTABLE TO DIFFERENCES IN TECHNIQUES OF pH MEASUREMENTS. THE SOIL HORIZONS FOLLOWED THE NORMAL TREND IN pH WITH LOWEST pH AT THE SURFACE AND INCREASING pH WITH DEPTH. ALL THE PODZOLIZED SANDY SOILS WITH A pH BELOW 5.0 IN THE UPPER HORIZONS SHOWED NO SIGNIFICANT DECREASE IN pH OVER THE 18-YEAR PERIOD FROM 1960 TO 1978. THE ONLY SOIL SERIES

TO DEMONSTRATE A DECLINE IN pH OVER THE 18-YEAR PERIOD WAS A NON-PODZOLIZED SOIL AND IT HAD A pH ABOVE 5.0 IN ALL HORIZONS IN 1960. THE pH OF THE SURFACE SOIL DECREASED FROM 5.7 IN 1960 TO 4.8 IN 1978 (LINZON AND TEMPLE 1980).

BASED ON RESEARCH COMPLETED TO DATE WITH SIMULATED ACIDIC RAIN, THE FINDINGS IN NATURE AND PEDOLOGICAL THEORIES, ONE MIGHT EXPECT, AS THE ACIDITY OF AMBIENT PRECIPITATION REACHES pH 4.0 AND LOWER, INCREASED CATION LEACHING IN SANDY SOILS THAT ARE MODERATELY BUFFERED, ALONG WITH A DECREASE IN SOIL pH. THE ACIDIFICATION OF SOIL WILL CAUSE AL AND OTHER METALS SUCH AS MN AND FE TO BECOME MORE SOLUBLE AND LEACH INTO THE SURROUNDING WATERS. SOIL BACTERIA MAY BE REDUCED IN NUMBER IN ACIDIFIED SOILS BUT FUNGI COULD INCREASE IN THEIR ACTIVITY. OTHER CHANGES SUCH AS REDUCTION IN SOIL RESPIRATION, NITRIFICATION AND LOSS OF CLAY MINERALS MAY OCCUR ALSO WITH LOWER PRECIPITATION ACIDITY (LINZON ET AL 1981B).

### 6.3 EFFECTS ON AGRICULTURE

IN EXPERIMENTS USING SIMULATED ACID RAIN, A NUMBER OF ADVERSE EFFECTS HAVE BEEN PRODUCED ON PLANT LIFE. THESE EFFECTS INCLUDE ALTERATIONS IN THE LEAF CUTICLE AND/OR FUNCTIONS OF GUARD CELLS, LESIONS ON LEAVES AND REPRODUCTIVE STRUCTURES, REDUCED CARBOHYDRATE STATUS, INCREASED LEACHING OF NUTRIENTS SUCH AS CALCIUM, MAGNESIUM AND POTASSIUM FROM FOLIAGE, OVERALL REDUCTIONS

IN PLANT PRODUCTIVITY AND MICROORGANISM STIMULATION OR INHIBITION (EVANS 1982).

MOST INVESTIGATORS HAVE NOT BEEN ABLE TO DOCUMENT CONCLUSIVELY THAT EFFECTS ON AGRICULTURAL CROPS ARE OCCURRING IN THE FIELD UNDER EXPOSURE TO CURRENT AMBIENT ACIDIC DEPOSITION. MANY NULLIFYING FACTORS ARE INVOLVED IN A MANAGED AGRICULTURAL OPERATION, SUCH AS CULTIVATION, ARTIFICIAL IRRIGATION, FERTILIZATION AND LIMING TO MAINTAIN FARMLAND AT AN OPTIMUM pH. HOWEVER, IN ONE INVESTIGATION IN WHICH GARDEN BEETS WERE EXPOSED TO BOTH SIMULATED ACIDIC RAIN AND AMBIENT RAINFALLS WITH A MEAN WEIGHTED pH OF 3.9, VISIBLE FOLIAR INJURY OCCURRED IN THE FIELD UNDER STANDARD AGRONOMIC CONDITIONS (EVANS ET AL 1982).

LEE ET AL (1980) REPORTED THE RESULTS OF SIMULATED SULPHURIC ACID RAIN ON 26 CROPS. AT A pH OF 3.0, THERE WAS A DECREASE IN DRY WEIGHT OF 10 CROPS, NO CHANGE IN 10 CROPS AND AN INCREASE IN DRY WEIGHT IN 6 CROPS. AT A pH OF 4.0, THERE WAS A DECREASE IN DRY WEIGHT IN 6 CROPS, NO CHANGE IN 12 CROPS AND AN INCREASE IN 8 CROPS. THE DECREASE IN DRY WEIGHT OF ROOT CROPS SUCH AS RADISH, CARROT AND BEET WAS AS HIGH AS 69 PERCENT AND THE DECREASE IN THE YIELD AND MARKETABILITY OF LEAF CROPS SUCH AS SPINACH, CABBAGE AND MUSTARD GREENS WAS AS HIGH AS 31 PERCENT.

SINCE VARIOUS INVESTIGATORS HAD BEEN OBTAINING DIFFERENT RESULTS IN EXPERIMENTS UTILIZING SIMULATED ACIDIC

SOLUTIONS, DUE TO DIFFERENCES IN METHODOLOGY AND CROP SPECIES AND CULTIVARS, AN INTERLABORATORY COOPERATIVE STUDY WAS INITIATED IN 1981. THE MAIN OBJECTIVE OF THE EXPERIMENT WAS TO STANDARDIZE TECHNIQUES AND PROCEDURES TO DETERMINE IF REASONABLE AGREEMENT OF RESULTS COULD BE ATTAINED AMONGST THE COOPERATING AGENCIES. SIX U.S. AND CANADIAN LABORATORIES PARTICIPATED IN THE EXPERIMENT AS FOLLOWS: (1) ONTARIO MINISTRY OF THE ENVIRONMENT (ONT), BRAMPTON, ONTARIO, (2) BOYCE THOMPSON INSTITUTE (BTI), CORNELL UNIVERSITY, ITHACA, NEW YORK, (3) BROOKHAVEN NATIONAL LABORATORY (BNL), LONG ISLAND, NEW YORK, (4) ARGONNE NATIONAL LABORATORY (ANL), ARGONNE, ILLINOIS, (5) OAK RIDGE NATIONAL LABORATORY (ORNL), OAK RIDGE, TENNESSEE AND (6) CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY (CERL), OREGON STATE UNIVERSITY, CORVALLIS, OREGON.

CHERRY BELLE RADISH WAS CHOSEN FOR THIS EXPERIMENT AND SEEDS WERE SUPPLIED FROM A SINGLE SOURCE TO MINIMIZE VARIABILITY. PROCEDURES FOR POTTING, TREATMENT APPLICATION, OBSERVATIONS AND HARVEST WERE STANDARDIZED, AND A COMMON SOIL, PROMIX BX WAS USED. EIGHT RAIN TREATMENTS (pH 2.6, 3.0, 3.4, 3.8, 4.2, 4.6, 5.0 AND 5.6) WERE PREPARED ACCORDING TO A RAIN CHEMISTRY RECIPE DERIVED BY THE ANL. EACH RAIN SIMULANT WAS BASED ON A 2.37:1 RATIO OF  $\text{SO}_4:\text{NO}_3$  BY GRAM WEIGHT. THE RADISHES WERE HARVESTED 28 DAYS AFTER PLANTING AND WET AND DRY WEIGHTS WERE DETERMINED.

THE LOWEST ACIDITY AT WHICH VISIBLE INJURY WAS OBSERVED WAS AT pH 3.4 FOR FOUR LABORATORIES (ANL, BNL, BTI, ORNL) AND pH 3.8 FOR TWO LABORATORIES (CERL, ONT). THE THRESHOLD OR LOWEST ACIDITY AT WHICH SIGNIFICANT NEGATIVE EFFECTS ON MARKETABLE YIELD WAS OBSERVED VARIED AMONG THE PARTICIPANTS BUT WAS ESTABLISHED AT pH 3.0 AFTER ANALYSIS OF THE POOLED DATA (TABLE 6.1) (IRVING ET AL 1982).

ALTHOUGH VISIBLE INJURY WAS APPARENT ON THE FOLIAGE OF THE RADISH PLANT AFTER TREATMENT WITH RAIN SIMULANTS WITH A pH OF 3.8, MICROSCOPICAL EXAMINATIONS WERE MADE OF THE HARVESTED RADISH FOLIAGE BY ONTARIO AND MINUTE LESIONS WERE OBSERVED ON FOLIAGE EXPOSED TO RAIN SIMULANTS WITH A pH OF EITHER 4.2 OR 4.6 (TUNG ET AL 1982). HISTOPATHOLOGICAL EXAMINATIONS OF FOLIAGE OF VARIOUS CROPS TREATED WITH SIMULATED ACID RAIN REVEALED A RANGE OF CELLULAR DERANGEMENTS, CONSISTING OF COLLAPSED EPIDERMAL CELLS, DEGRADATION OF CHLOROPHYLL IN MESOPHYLL PARENCHYMA AND STIMULATION OF IRREGULAR CELL GROWTH SUCH AS HYPERTROPHY AND HYPERPLASIA (TUNG ET AL 1982).

ACIDIC PRECIPITATION CAN ALTER HOST-PARASITE INTERACTIONS. SHRINER (1978) REPORTED A DECREASE IN THE PERCENTAGE OF LEAF AREA AFFECTED BY RUST DISEASE ON BEAN PLANTS EXPOSED TO SIMULATED RAIN. BISESSAR ET AL (1984) FOUND BACTERIAL SPECK OF TOMATO WAS INHIBITED BY SIMULATED ACIDIC RAIN, WITH THE INHIBITION BEING GREATER ON PLANTS EXPOSED TO ACIDIC RAIN AFTER INOCULATION THAN ON THOSE EXPOSED TO ACIDIC RAIN BEFORE INOCULATION.

THE INTERACTION OF OZONE AND ACIDIC RAIN MAY ENHANCE ADVERSE EFFECTS ON CROPS. JACOBSON ET AL (1980), USING OPEN-TOP EXPOSURE CHAMBERS WITH FIELD-GROWN SOYBEANS, COMPARED GROWTH AND YIELD BETWEEN THREE pH LEVELS OF SIMULATED RAIN (pH 2.8, 3.4 AND 4.0) AND TWO LEVELS OF OZONE (0.03 AND 0.12 PPM). RESULTS DEMONSTRATED THAT OZONE DEPRESSED BOTH GROWTH AND YIELD OF SOYBEANS WITH ALL THREE RAIN TREATMENTS, BUT THAT THE DEPRESSION WAS GREATEST WITH THE MOST ACIDIC RAIN.

#### 6.4 EFFECTS ON FORESTRY

THE EFFECTS OF ACIDIC DEPOSITION ON FORESTRY WERE VAGUE UNTIL 1980. IN SWEDEN, JONSSON AND SUNDBERG (1972) REPORTED FOREST PRODUCTIVITY LOSSES FOR SCOTS PINE AND NORWAY SPRUCE FOR THE PERIOD 1950 TO 1965 IN SUSCEPTIBLE AREAS AND CONCLUDED THAT ACIDIFICATION COULD NOT BE RULED OUT AS THE CAUSE. OTHER SWEDISH FOREST SCIENTISTS, E.G. TAMM (1976), INDICATED THAT ADDITIONAL FACTORS WERE RELATED SUCH AS GENOTYPE, TREE AGE, COMPETITION FROM NEIGHBOURING TREES AND SITE CONDITIONS. HOWEVER, BASED ON EXPERIMENTAL EVIDENCE, TAMM CONCLUDED THAT SCANDINAVIAN FORESTS WOULD BECOME LESS PRODUCTIVE IN THE LONG RUN.

IN 1982, AT THE STOCKHOLM CONFERENCE ON THE ACIDIFICATION OF THE ENVIRONMENT, PAPERS WERE PRESENTED ON THE IMPACT OF ACIDIC DEPOSITION ON FOREST GROWTH (ANDERSSON 1982). THREE PHASES WERE IDENTIFIED. IN PHASE 1, TREE GROWTH IS STIMULATED DUE TO AN IMPACT OF GROWTH LIMITING ELEMENTS,

IN PARTICULAR NITROGEN, AND IN SOME CASES SULPHUR. IN PHASE II, INCREASED ACIDIC DEPOSITION RESULTS IN DEPLETION OF SOIL NUTRIENTS, BY LEACHING BASE CATIONS, LEADING TO A DECREASED BASE SATURATION IN THE SOIL. SCANDINAVIA FALLS INTO PHASE I AND II CATEGORIES, DEPENDING ON LOCATION. IN PHASE III, CONTINUED SOIL ACIDIFICATION LEADS TO A RELEASE OF ALUMINUM AND HEAVY METALS TO CONCENTRATIONS RESULTING IN TOXIC EFFECTS ON TREE ROOTS. CENTRAL EUROPE, IN PARTICULAR PARTS OF WEST GERMANY, FALL INTO PHASES II AND III.

ULRICH ET AL (1980) PUBLISHED A PAPER DESCRIBING SOIL FOREST EFFECTS IN THE SOLLING HIGHLANDS, ABOUT 60 KM NW OF GOTTINGEN IN WEST GERMANY. AT SOLLING, THERE WAS AN INCREASE IN FREE ALUMINUM IN SOIL SOLUTION WHICH WAS ASSOCIATED WITH INCREASED MORTALITY OF THE FINE ROOTS OF EUROPEAN BEECH. DR. ULRICH'S THEORY FOR THIS EFFECT IS THAT DURING WARM, DRY SUMMERS, INCREASED NITRIFICATION OCCURS IN THE SOIL, WHICH RESULTS IN INCREASED PRODUCTION OF HYDROGEN IONS ( $H^+$ ), INCREASED SOIL ACIDITY, INCREASED MOBILIZATION OF ALUMINUM FROM ALUMINUM SILICATES IN THE SOIL AND TOXIC EFFECTS OF ALUMINUM ON THE FINE ROOTS OF TREES. ACID DEPOSITION CAN ADD TO THIS STRESS. ALUMINUM

BECOMES TOXIC WHEN THE CALCIUM:ALUMINUM RATIO IN SOIL SOLUTION FALLS BELOW 1. WHEN THIS RATIO DECREASES,

WATER NUTRIENT UPTAKE BY TREE ROOTS IS REDUCED.

DISCOLORATION, FOLIAR LOSS AND OTHER STRESSORS. ALSO,

DRYNESS OF THE ROOTS AND TREE TRUNKS MAKES THE TREES MORE PRONE TO WINDTHROW AND TRUNK BREAKAGE.

BAUCH AND SCHRODER (1982) STUDIED THE DISTRIBUTION OF SOME ELEMENTS IN CELLS OF THE FINE ROOTS OF AFFECTED AND HEALTHY SPRUCE AND FIR TREES IN WEST GERMANY. IN AFFECTED TREES, CALCIUM AND MAGNESIUM CONTENTS WERE EXTREMELY LOW, SUGGESTING AN INTERACTION WITH ALUMINUM.

IN THE LAST THREE YEARS (SINCE 1980), FORESTS THROUGHOUT WEST GERMANY HAVE BEEN EXHIBITING VARIOUS DEGREES OF DAMAGE CONSISTING OF YELLOWING FOLIAGE, EARLY SHEDDING OF LEAVES (ESPECIALLY OLDER LEAVES FROM BRANCHES IN THE MID-CROWN OF THE TREES), BRANCH DIEBACK AND TREE DEATH. THE TREE SPECIES AFFECTED INCLUDE NORWAY SPRUCE, EUROPEAN BEECH, SILVER FIR AND SCOTS PINE. A 1982 SURVEY INDICATED THAT FOREST DAMAGE IN WEST GERMANY AFFECTED A TOTAL AREA ESTIMATED AT 560,000 HECTARES (OR ABOUT 8% OF ALL THE FORESTS IN WEST GERMANY). A RECENT SURVEY IN 1983 INDICATES THAT THE FOREST DAMAGE HAS INCREASED TO 2,500,000 HECTARES OR ABOUT 35% OF THE TOTAL AREA.

THE FEDERAL GOVERNMENT OF WEST GERMANY HAS PRODUCED A RECENT REPORT ON "FOREST DAMAGE DUE TO AIR POLLUTION" (1982), PREPARED BY THE FEDERAL MINISTRY OF FOOD, AGRICULTURE AND FORESTRY, THE MINISTRY OF THE INTERIOR AND THE LAENDER COMMITTEE FOR ENVIRONMENTAL PROTECTION. IN THIS REPORT, IT WAS CONCLUDED THAT TREE DAMAGE IN WEST GERMANY WAS THE RESULT OF SEVERAL CAUSES, INCLUDING AIR POLLUTION (SULPHUR DIOXIDE, NITROGEN OXIDES, OZONE AND HEAVY METALS), DROUGHT, FROST, FORESTRY MANAGEMENT, INSECTS AND DISEASE. THE PROPORTION TO WHICH EACH

INDIVIDUAL FACTOR CONTRIBUTED TO THE DAMAGE DIFFERED FROM SITE TO SITE DEPENDING ON DIFFERENT CONDITIONS. HOWEVER, THE MAJOR FACTOR IN MOST CASES WAS BELIEVED TO BE ATMOSPHERIC SULPHUR DIOXIDE AND ITS CONVERSION PRODUCTS.

IN ORDER TO BETTER DEFINE THE PRECISE CAUSE AND EFFECT RELATIONSHIPS, THE BMFT RESEARCH MINISTRY OF W. GERMANY, IN JANUARY, 1983, APPROVED FUNDING OF ABOUT DM 5 MILLION TO UNIVERSITIES AND TECHNICAL INSTITUTIONS TO CONDUCT RESEARCH ON THE EFFECTS OF ACID RAIN ON FORESTS AND SOIL.

IN THE UNITED STATES, DECLINING GROWTH OF FOREST TREES HAVE BEEN REPORTED IN NEW JERSEY, NEW YORK, VERMONT AND NEW HAMPSHIRE. SEVERAL INVESTIGATORS HAVE IMPLICATED ACIDIC DEPOSITION AS POSSIBLY CONTRIBUTING TO THE DECLINE. JOHNSON ET AL (1981) REPORTED THAT PITCH, SHORTLEAF AND LOBLOLLY PINE TREES GROWING IN THE NEW JERSEY PINE BARRENS HAD EXHIBITED DECREASES IN GROWTH RATES WHICH CORRELATED STATISTICALLY WITH DECREASES IN STREAM pH. ~~VOGELMANN (1982)~~ REPORTED THAT RED SPRUCE SHOWED A DECLINE IN BASAL AREA OF 50 PERCENT IN THE LAST TWO DECADES AT CAMELS HUMP, VERMONT. IN ADDITION, ~~SUGAR MAPLE AND BEECH SHOWED DECLINES OF 30 AND 14 PERCENT, RESPECTIVELY FOR THE SAME TIME PERIOD.~~ VOGELMANN HAS PRESENTED CIRCUMSTANTIAL EVIDENCE THAT ACIDIC PRECIPITATION AND HEAVY METAL DEPOSITION MAY BE RESPONSIBLE. THE SOILS AT HIGH ALTITUDES ARE THIN AND ACIDIC AND THE TREES ARE OFTEN EXPOSED TO ACIDIC FOGS. THE DECLINE AND DEATH OF FOREST TREES IN THE NORTHEASTERN UNITED STATES ARE NOW THE SUBJECT OF ONGOING RESEARCH IN

ORDER TO RESOLVE THE PRECISE ROLE OF ACIDIC DEPOSITION. NOTWITHSTANDING THAT ACIDIC DEPOSITION MAY EITHER BE A TRIGGERING MECHANISM OR AN EXACERBATING FACTOR IN THE CONTINUAL DECLINE OF SEVERAL FOREST TREE SPECIES IN THE NORTHEASTERN STATES, STUDIES ARE UNDERWAY TO EXAMINE THE CONTRIBUTIONS BY OTHER POSSIBLE AGENTS SUCH AS DROUGHT, INSECTS AND DISEASE.

IN CANADA, PERCY (1982) STUDIED THE EFFECTS OF SIMULATED ACID RAIN ON SEED GERMINATION AND THE DEVELOPMENT OF SPRUCE AND PINE SEEDLINGS. SPRUCE WAS MORE SENSITIVE TO ACIDIC SOLUTIONS THAN PINE, WITH INHIBITION OF PRIMARY AND SECONDARY NEEDLE INITIATION OCCURRING IN SPRUCE SEEDLINGS FROM EXPOSURE TO ACIDIC SOLUTIONS WITH A pH OF 4.6. COX (1982) STUDIED THE EFFECTS OF SIMULATED ACID RAIN ON THE REPRODUCTIVE PROCESSES OF FOREST FLORA SPECIES. POLLEN GERMINATION AND POLLEN TUBE ELONGATION IN SUGAR MAPLE WERE AFFECTED AT pH 4.0 AND POLLEN GERMINATION IN AN EVENING PRIMROSE VARIETY WAS AFFECTED BY pH 4.6.

#### 6.5 DISCUSSION AND SUMMARY OF TERRESTRIAL EFFECTS

THERE IS MOUNTING EVIDENCE OF THE DECLINE OF FOREST TREE SPECIES IN SEVERAL PARTS OF THE WORLD AND OF CROPS AND SOILS BEING THREATENED BY ACIDIC DEPOSITION. STUDIES IN FIELD SITUATIONS WHERE SULPHATE LOADINGS ARE HIGH HAVE DEMONSTRATED INCREASED LEACHING OF BASIC CATIONS FROM SOIL AND ACCELERATED REMOVAL OF ALUMINUM FROM SOILS TO WATERBODIES. A NUMBER OF ADVERSE EFFECTS HAVE BEEN

DOCUMENTED FOR BOTH SOILS AND PLANT LIFE EXPOSED TO SIMULATED ACIDIC SOLUTIONS. GENERALLY SOLUTIONS WITH A pH ABOUT TEN TIMES GREATER THAN THAT FOUND IN AMBIENT PRECIPITATION HAVE BEEN RESPONSIBLE FOR THE ADVERSE EFFECTS. HOWEVER, IN SOME CASES, SOLUTIONS WITH A pH AS HIGH AS 4.6 HAVE BEEN SHOWN TO CAUSE LEAF LESIONS, INTERFERE WITH REPRODUCTIVE PROCESSES AND INHIBIT NEEDLE INITIATION IN TREE SEEDLINGS.

IN WEST GERMANY AND SOME NORTHEASTERN STATES, SEVERAL FOREST TREE SPECIES HAVE DECLINED IN RECENT YEARS. HOW MUCH OF THIS DECLINE IS DUE TO CURRENT DEPOSITION OF ACIDIC SUBSTANCES OR TO A LATENT REACTION TO SEVERAL DECADES OF EXPOSURE TO ENHANCED AIR POLLUTION IS NOT CLEAR. EQUALLY UNCLEAR AT THE PRESENT TIME IS HOW MUCH OF THE DECLINE IS DUE TO OTHER CAUSAL AGENTS SUCH AS INSECTS, DISEASE, DROUGHT OR TO THE INTERACTION OF ACIDIC PRECIPITATION WITH ATMOSPHERIC OZONE AND DEPOSITED HEAVY METALS.

HOWEVER, IT IS REASONABLE TO BELIEVE THAT INCREASING EMISSIONS OF THE PRECURSOR POLLUTANTS TO ACIDIC DEPOSITION CAN ONLY LEAD TO CONTINUED SOIL DEGRADATION AND INDIRECT ADVERSE EFFECTS ON FOREST GROWTH. THE RECOGNITION OF THE POTENTIAL THREAT TO TERRESTRIAL RESOURCES IN LOCATIONS SUBJECTED TO HIGH ACIDIC LOADINGS HAS LED THE ONTARIO MINISTRY OF THE ENVIRONMENT TO UNDERTAKE AN INTENSIVE PROGRAM OF MONITORING, SURVEILLANCE AND EXPERIMENTATION TO BETTER DEFINE THE EFFECTS OF ACIDIC DEPOSITION ON SOIL AND VEGETATION.

TABLE 6.1. HIGHEST pH OF RAIN TREATMENT RESULTING IN  
SIGNIFICANT NEGATIVE EFFECTS ON THE YIELD OF  
RADISHES.

LABORATORY	THRESHOLD pH
ANL	3.4
BNL	4.6
BTI	2.6
CERL	3.0
ORNL	2.6
ONT	3.0
POOLED	3.0

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## 7. ONTARIO'S EFFORTS

### 7.1 SULPHUR DIOXIDE ABATEMENT

ONTARIO HAS RECOGNIZED THAT IT IS PART OF THE PROBLEM, AND, THEREFORE, MUST BE PART OF THE SOLUTION.

TO IMPROVE LOCAL AIR QUALITY, AVERAGE ANNUAL EMISSIONS OF SULPHUR DIOXIDE FROM ~~ONTARIO~~ SOURCES WERE REDUCED FROM

~~2.8 MILLION METRIC TONS IN 1970 TO 1.7 MILLION METRIC~~

~~TONS IN 1980~~. PRELIMINARY ESTIMATES OF 1982 EMISSIONS INDICATE THAT SULPHUR OXIDE EMISSIONS TOTALLED 1.12 MILLION METRIC TONS (ONTARIO MINISTRY OF TREASURY AND ECONOMICS 1983). IN ADDITION, PROGRAMS HAVE BEEN ESTABLISHED AT ALL MAJOR ONTARIO SOURCES TO REDUCE EMISSIONS WHEN ATMOSPHERIC CONDITIONS REQUIRE IT.

HOWEVER, DURING 1979/1980, RESULTS FROM OUR SCIENTIFIC RESEARCH PROGRAM WERE ALREADY DEMONSTRATING THAT MORE NEEDED TO BE DONE BY ONTARIO AND BY OTHER JURISDICTIONS TO REDUCE THE IMPACT OF LONG RANGE TRANSPORT OF AIRBORNE POLLUTANTS.

THE MEMORANDUM OF INTENT, SIGNED BY CANADA AND THE UNITED STATES IN AUGUST 1980, WAS AN IMPORTANT FIRST STEP TOWARDS COMBATting THE LONG RANGE TRANSPORT PROBLEM.

ONTARIO ALSO CONSIDERED CANADA'S COMMITMENT UNDER THE MEMORANDUM OF INTENT TO BE A SERIOUS ONE AND HAS, THEREFORE, IMPOSED SO<sub>2</sub> EMISSION LIMITS ON ITS TWO MAJOR

SOURCES - [REDACTED]

IN ORDER TO MEET THIS OBJECTIVE, SEVERAL ACTIVITIES ARE UNDERWAY.

7.2.1 [REDACTED] ATMOSPHERIC PROCESSES STUDIES

IN RESPONSE TO THE NEED TO UNDERSTAND THE ACID RAIN AND THE LONG RANGE TRANSPORT OF POLLUTANTS PHENOMENA, THE ONTARIO MINISTRY OF THE ENVIRONMENT SET UP TWO NETWORKS TO MONITOR BOTH WET AND DRY DEPOSITION OF SELECTED POLLUTANTS, IN THE LATTER PART OF 1980.

THE [REDACTED] BEGAN ITS OPERATION IN SEPTEMBER, 1980 AT 32 SAMPLING SITES, WHICH WERE DISTRIBUTED MORE DENSELY IN SOUTHERN ONTARIO THAN NORTHERN ONTARIO. BY MID-1982, THE NETWORK HAD BEEN EXPANDED TO 36 SITES. ITS PURPOSE IS TO DETERMINE THE LONG TERM DEPOSITION PATTERN IN ONTARIO.

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THE ANNUAL DEPOSITION FIELDS OF SEVERAL PARAMETERS, NOTABLY SULPHATES AND NITRATES, SHOW THE GENERAL FEATURES PREDICTED BY CURRENT LONG-RANGE TRANSPORT MODELS, WITH MUCH HIGHER VALUES IN THE SOUTHERN THAN THE NORTHERN PART OF THE PROVINCE. RESULTS FROM THIS NETWORK SHOW THAT THE WET SULPHATE LOADING OF 20 KG/HA·YR, WHICH HAS BEEN SUGGESTED BY CANADIAN SCIENTISTS AS BEING CRITICAL FOR SENSITIVE WATER BODIES, IS EXCEEDED IN ALL OF SOUTHERN ONTARIO. FURTHERMORE, THE AVERAGE PH OF RAINFALL IN SOUTHERN ONTARIO IS 4.2 AND, IN ONTARIO'S SENSITIVE MUSKOKA-HALIBURTON REGION, RAINFALL WITH A PH AS LOW AS 3.3. HAS BEEN RECORDED.

THE SECOND NETWORK IS AN ~~EVENT NETWORK~~, WHICH SAMPLES ON A DAILY BASIS, AND IS DESIGNED TO DEFINE THE SECTOR OF ORIGIN OF THE POLLUTANTS AT THE RECEPTORS, AS WELL AS THE FREQUENCY AND INTENSITY OF ACIDIC DEPOSITION EPISODES.

ANALYSIS OF THE EVENT NETWORK RESULTS HAS DEMONSTRATED THE IMPORTANCE OF LONG RANGE TRANSPORT FROM THE SOUTH TO THE MONITORING SITES IN ONTARIO AND THAT THE IMPACTS FROM LONG RANGE TRANSPORT CANNOT BE SOLVED BY ABATEMENT ACTION IN ONTARIO ALONE.

THE DEPOSITION MONITORING RESULTS AND UP-TO-DATE EMISSIONS DATA FORM PART OF THE INPUT FOR TWO MODELS CURRENTLY UNDER DEVELOPMENT BY ONTARIO. THE ~~MODELS~~

~~MODELS ARE THE AVERAGE POLLUTANT CONCENTRATIONS AND THE SHORT-RANGE SOURCES AND RECEPTORS.~~

~~ANALYSIS.~~ THE STATISTICAL MODEL HAS BEEN APPLIED FOR EMISSION SCENARIO STUDIES TO DETERMINE THE EFFECT OF REDUCTIONS IN EMISSIONS AT CERTAIN SOURCES ON SPECIFIC RECEPTOR AREAS.

IN ADDITION, THE PROVINCE OF ONTARIO IS CO-FUNDING WITH ENVIRONMENT CANADA AND THE UMWELTBUNDESAMT OF ~~GERMANY~~

~~GERMANY~~ THE DEVELOPMENT OF AN ~~EUROPEAN MODEL~~ FOR ACID DEPOSITION AND OXIDANTS WHICH WILL INCORPORATE DETAILED CHEMICAL TRANSFORMATIONS AND DEPOSITION OF ATMOSPHERIC POLLUTANTS. THIS STATE-OF-THE-ART MODEL WILL BE ~~USED~~

~~LINK SOURCES WITH RECEPTORS IN ORDER TO DETERMINE THE~~

~~MOST ENVIRONMENTAL PROTECTION MEASURES ARE  
EXPECTED TO BE OPERATIONAL BY 1986~~

#### 7.2.2 AQUATIC EFFECTS STUDIES

RESULTS FROM OUR EXTENSIVE SURVEY OF LAKES IN THE PROVINCE PROVIDE SOME INDICATION OF THE SUSCEPTIBILITY OF THE PROVINCE'S AQUATIC SYSTEMS TO ACID RAIN.

TO DATE, 4,016 LAKES HAVE BEEN SAMPLED IN THE PROVINCE. OF THESE LAKES, 155 OR 3.9% WERE FOUND TO BE ACIDIFIED TO THE EXTENT THAT THEIR ABILITY TO SUPPORT AQUATIC LIFE IS EXTREMELY LIMITED. A TOTAL OF 2,896 LAKES, ACCOUNTING FOR 72.2% OF THOSE SURVEYED, WERE FOUND TO HAVE SOME SUSCEPTIBILITY TO ACIDIFICATION (13% WERE EXTREMELY SENSITIVE, 41.1% WERE MODERATELY SENSITIVE AND 18.1% WERE OF LOW SENSITIVITY). TWENTY-FOUR PERCENT (96 LAKES) WERE FOUND TO BE NOT SENSITIVE TO THE CUMULATIVE EFFECTS OF ACID RAIN.

THESE SURVEY RESULTS HIGHLIGHT THE CRITICAL NATURE OF THE ACID RAIN PROBLEM FOR ONTARIO SINCE NEARLY TEN PERCENT OF ONTARIO'S ECONOMIC BASE COMES FROM THE AQUATIC-BASED TOURISM AND OUTDOOR RECREATION INDUSTRIES.

IN ADDITION TO THIS EXTENSIVE PROVINCIAL SURVEY, INTENSIVE CALIBRATED WATERSHED STUDIES ARE BEING CONDUCTED ON EIGHT LAKES IN THE MUSKOKA-HALIBURTON AREA, A SENSITIVE RECREATIONAL AREA ON THE PRECAMBRIAN SHIELD

ABOUT 300 KM (180 MILES) N. OF TORONTO. RESULTS OF THIS INTENSIVE RESEARCH ARE DESCRIBED IN CHAPTER 5 (SPECIFICALLY SECTION 5.4).

THESE RESULTS ARE BEING INCORPORATED IN THE WATER CHEMISTRY MODELS BEING DEVELOPED FOR LAKES AND STREAMS AS A MEANS OF ASSESSING OUR UNDERSTANDING OF THE ACIDIFICATION OF THE AQUATIC ENVIRONMENT. THESE MODELS PROVIDE AN IMPORTANT TOOL FOR PREDICTING EITHER THE EFFECTS OF ABATEMENT MEASURES OR THE FURTHER DETERIORATION OF IMPACTED AQUATIC SYSTEMS IF ABATEMENT MEASURES ARE DELAYED.

SINCE ONTARIO HAS SUCH A LARGE NUMBER OF LAKES AND IT IS NOT POSSIBLE TO MONITOR ALL OF THEM INTENSIVELY, THE DEVELOPMENT OF AQUATIC MODELS AND CONTINUED DOCUMENTATION OF BIOLOGICAL EFFECTS ASSOCIATED WITH ACIDIFICATION WILL PROVIDE THE BASIS FOR EXTRAPOLATION OF THIS KNOWLEDGE SO THAT PREDICTIONS CAN BE MADE OF THE EFFECTS OF ACIDIFICATION ON LAKES NOT BEING MONITORED.

FURTHERMORE, ONTARIO IS CO-FUNDING AN EXPERIMENT TO DETERMINE WHETHER AN AREA THAT HAS ALREADY BEEN ACIDIFIED CAN RECOVER IF THE ACIDIFICATION IS STOPPED. THIS FIVE YEAR EXPERIMENT IS BEING CARRIED OUT BY THE NORWEGIAN INSTITUTE FOR WATER RESEARCH (N.I.V.A.) IN THE BIRKENES AREA OF NORWAY.

### 7.2.3 TERRESTRIAL EFFECTS STUDIES

THE ONTARIO MINISTRY OF THE ENVIRONMENT, THROUGH ITS ACIDIC PRECIPITATION IN ONTARIO STUDY (A.P.I.O.S), EMBARKED ON AN INTENSIVE PROGRAM OF STUDYING THE EFFECTS OF ACIDIC DEPOSITION ON TERRESTRIAL RESOURCES IN 1980. THE PROGRAM HAS BEEN SEGREGATED INTO THREE AREAS: SOILS, VEGETATION AND BIOGEOCHEMISTRY. ALTHOUGH THE MINISTRY OF THE ENVIRONMENT HAS THE LEAD ROLE IN THIS PROGRAM, OTHER MINISTRIES SUCH AS NATURAL RESOURCES AND AGRICULTURE AND FOOD, CONTRIBUTE THROUGH THEIR PARTICIPATION IN THE TERRESTRIAL EFFECTS WORKING GROUP.

THE SOILS PROGRAM CONSISTS OF A BASELINE STUDY CONDUCTED THROUGHOUT ONTARIO. THIS SURVEY WAS STARTED IN 1980 AND, TO DATE, OVER 300 PERMANENT SOIL SITES ON VARIOUS LANDFORMS HAVE BEEN ESTABLISHED. THIS STUDY WAS FOUND NECESSARY, SINCE GOOD HISTORICAL DATA WERE NONEXISTENT IN THE AREA OF SOIL SURVEYS CONDUCTED FOR THE PURPOSE OF DOCUMENTING THE EFFECTS OF ACIDIC RAINFALL. AT EACH SOIL SITE ESTABLISHED SINCE 1980, PHYSICAL AND CHEMICAL DATA HAVE BEEN COLLECTED, WITH SOIL SAMPLES BEING ANALYZED FOR 30 DIFFERENT PARAMETERS. THE SAME SOIL SITES AT THE PRECISELY DEFINED LOCATIONS WILL BE EXAMINED PERIODICALLY USING THE SAME COLLECTION AND ANALYTICAL METHODS. INFORMATION DERIVED FROM THESE STUDIES WILL HELP IN THE DETERMINATION OF THE RATE OF DEGRADATION OF SOIL IN ONTARIO AND IN THE MAPPING OF LOCATIONS SENSITIVE TO ACIDIC DEPOSITION. OTHER SOIL STUDIES INCLUDE SITE

THE VEGETATION PROGRAM IS PRIMARILY EXPERIMENTAL, WITH VARIOUS CROP AND TREE SPECIES BEING SUBJECTED TO SIMULATED ACID RAIN IN ORDER TO DETERMINE DOSE-RESPONSE, SYMPTOMATOLOGY, SENSITIVITY OF SPECIES AND CULTIVARS AND EFFECTS ON GROWTH AND YIELD. THESE EXPERIMENTS ARE CONDUCTED FOR THE MOST PART IN SPECIALLY CONSTRUCTED FACILITIES AT BRAMPTON, ONTARIO. TWO TYPES OF RAIN SIMULATION FACILITIES ARE LOCATED AT BRAMPTON CONSISTING OF INDOOR LABORATORY CHAMBERS AND AN OUT-OF-DOOR EXCLUSION CANOPY SYSTEM. FOUR RAIN-TESTING FACILITIES

[REDACTED] Y,  
[REDACTED] R

~~HEIGHT TO TANK~~

THE RAIN TREATMENTS RANGE BETWEEN pH OF 2.6 TO 5.6 WITH THE RAIN SIMULANTS HAVING A SIMILAR IONIC STRENGTH AS FOUND IN AMBIENT RAIN IN SOUTHERN ONTARIO, E.G. THE ~~SO<sub>4</sub>:NO<sub>3</sub> RATIO IS 2:5:1 BY GRAM WEIGHT.~~

THE OUTDOOR EXCLUSION CANOPY SYSTEM WILL ENABLE  
EXPERIMENTS TO BE CONDUCTED ON CROPS GROWN IN THE FIELD  
FROM SEED TO HARVEST. ~~THE LARGE INDUSTRY EXTENSION~~

CONFIDENTIAL

AMBIENT RAIN AS WELL AS TO APPLY ACID RAIN TREATMENTS. A COMPUTER ACTIVATES THE CANOPIES AND THE SIMULATED ACID RAIN TREATMENTS. GASEOUS POLLUTANTS ARE ALSO REDUCED IN THE AIR SURROUNDING THE FIELD GROWN CROPS. IN ADDITION TO EXCLUDING AMBIENT ACID RAIN AND GASEOUS POLLUTANTS, THE ~~ENTERED CANOPY~~ CONCENTRATIONS OF GASEOUS ~~SULPHUR~~ TO DETERMINE THE ~~STIMULANT~~ STIMULANTS.

BIOGEOCHEMISTRY ARE BEING CONDUCTED ~~LEAF~~ ~~LOAD~~ ~~LOADING~~ ~~TO~~ ~~LOAD~~ (NEAR ~~TRUNK~~) ~~TO~~ CLOSE TO BACKGROUND.

THESE STUDIES WILL ATTEMPT TO DOCUMENT THE RATE AND MAGNITUDE OF NUTRIENT AND HEAVY METAL INPUTS, LOSSES AND INTERNAL CYCLING. INCOMING ACIDIC PRECIPITATION IS COLLECTED IN THE FOREST BY INCIDENT, THROUGHFALL AND STEMFLOW MEANS. LYSIMETERS COLLECT SOIL LEACHATES AND THE COLLECTED AQUEOUS SAMPLES ARE ANALYZED IN THE LABORATORY FOR UP TO 30 DIFFERENT PARAMETERS. LITTERFALL IS ALSO COLLECTED FOR ANALYSIS. THE FOREST BIOMASS IS DETERMINED BY ANALYZING TREE ROOTS, TRUNK, BRANCHES AND FOLIAGE IN CONJUNCTION WITH A COMPLETE FOREST INVENTORY.

INFORMATION DERIVED FROM THESE STUDIES WILL HELP PREDICT CHANGES IN FOREST PRODUCTIVITY WHICH CAN BE EXPECTED FROM INCREASES OR DECREASES IN SULPHATE OR NITRATE DEPOSITION IN PRECIPITATION. FURTHER, BY FOLLOWING SEQUENTIALLY THE PATHWAY OF CATIONS AND ANIONS IN RAIN THROUGH THE FOREST CANOPY, SOIL, GROUNDWATER AND STREAMS, THE ROLE THAT THE TERRESTRIAL SYSTEM PLAYS IN LAKE ACIDIFICATION CAN BE ELUCIDATED.

FIELD VEGETATION STUDIES ALSO INCLUDE SURVEYS OF EPIPHYTIC MOSSES AND LICHENS IN SELECTED AREAS IN ONTARIO TO IDENTIFY THEIR CURRENT VIABILITY AND DISTRIBUTION AND TO DETECT FUTURE ALTERATIONS.

COOPERATIVE STUDIES ARE BEING UNDERTAKEN WITH THE U.S.A. IN STUDYING ALUMINUM BIOGEOCHEMISTRY AND TOXICITY TO TREES AND IN EVALUATING TREE GROWTH TRENDS OVER THE PAST 50 YEARS AND THEIR RELATION TO AIR POLLUTION STRESS.

#### 7.2.4 SOCIOECONOMIC INVESTIGATIONS

SEVERAL SOCIOECONOMIC STUDIES HAVE BEEN COMPLETED IN THE PROVINCE OF ONTARIO TO IDENTIFY THE DAMAGES DUE TO ACID RAIN AND TO ESTIMATE THE BENEFITS OF ITS CONTROL. MODELS TO ANALYZE THE BIOPHYSICAL AND ECONOMIC CONSEQUENCES OF THE EFFECTS OF ACID RAIN ON AQUATIC-BASED RECREATION AND TOURISM AND TERRESTRIAL AND AQUATIC RESOURCE SECTORS, HAVE BEEN DEVELOPED. IN ADDITION, A SURVEY OF RESIDENTS AND TOURISTS WAS UNDERTAKEN TO ASCERTAIN THE VALUE AND IMPORTANCE THEY PLACE ON ENVIRONMENTAL RESOURCES AFFECTED

BY ACID RAIN. IT IS EVIDENT THAT THERE IS WIDESPREAD CONCERN ABOUT THE EFFECTS AND THE DECLINE IN ENVIRONMENTAL QUALITY. FURTHERMORE, POTENTIAL TECHNOLOGIES AND COSTS OF ADDITIONAL ABATEMENT AT VARIOUS MAJOR ONTARIO SOURCES ARE BEING STUDIED.

INFORMATION IN BOTH THESE AREAS IS NEEDED TO DEVELOP A COST-EFFECTIVE ABATEMENT STRATEGY FOR THE PROVINCE, NOT ONLY AS A COMPONENT OF AN OVERALL EASTERN CANADA ABATEMENT PROGRAM, BUT ALSO AS PART OF A STRATEGY TO CURTAIL ACID RAIN IN EASTERN NORTH AMERICA.

IN ORDER TO DEVELOP AND EVALUATE ABATEMENT STRATEGIES, THE MINISTRY HAS DEVELOPED A COMPUTERIZED [REDACTED] MODEL. THIS MODEL HELPS TO FIND ACID RAIN CONTROL STRATEGIES WHICH ACHIEVE TARGET ACIDIC DEPOSITION LEVELS IN SENSITIVE AREAS AT THE LOWEST TOTAL COST. THIS TOOL IS CURRENTLY BEING USED IN INTERGOVERNMENTAL DELIBERATIONS.

### 7.3 SUMMARY

THE PROVINCE OF ONTARIO HAS DEDICATED MUCH OF ITS RESOURCES AND EFFORTS TO SOLVING THE ACID PRECIPITATION PROBLEM.

ONTARIO'S COMMITMENT IS ILLUSTRATED NOT ONLY BY ITS COMPREHENSIVE RESEARCH PROGRAM BUT ALSO BY THE ABATEMENT MEASURES IT HAS IMPLEMENTED TO DATE.

THIS DEMONSTRATES THAT ONTARIO'S CITIZENS ARE AWARE OF THE ACID RAIN PROBLEM AND THE NEED FOR ITS SOLUTION.

IT IS NOT SIMPLY A POPULAR POLITICAL ISSUE, BUT A MATTER WHICH HAS TRANSCENDED ORDINARY PARTISAN LINES IN THE PROVINCE AND IN THE COUNTRY. THERE IS NO QUESTION THAT ACTION MUST BE TAKEN TO SIGNIFICANTLY DECREASE THE CAUSES; THE ONLY QUESTIONS ARE HOW FAR AND HOW FAST.

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## 8. CRITIQUE OF THE COST-BENEFIT ANALYSES

### 8.1 INTRODUCTION

CONSUMERS POWER COMPANY SUBMITTED COST-BENEFIT ANALYSES WITH ITS APPLICATIONS TO THE AIR POLLUTION CONTROL COMMISSION. THE COSTS OF TWO ALTERNATIVE TECHNOLOGIES THAT ARE PROPOSED TO ACHIEVE THE EQUIVALENT OF 1% SULPHUR IN FUEL EMISSION LEVELS ARE COMPARED WITH THE ESTIMATES OF THE MONETARY VALUES OF SOME OF THE BENEFITS OF REDUCING SO<sub>2</sub> EMISSIONS FROM CURRENT LEVELS. BASED ON THESE ANALYSES THE COMPANY ARGUES, FOR EACH PLANT, THAT

"... COMPLIANCE WITH AMBIENT AIR QUALITY STANDARDS WILL CONTINUE TO BE ASSURED WHILE BURNING FUELS WITH THE SULPHUR CONTENT PROPOSED IN THE REQUEST, THUS ASSURING THE PROTECTION OF THE PUBLIC HEALTH AND WELFARE. THE COMPANY CONCLUDES THAT THE COST OF REDUCING SULPHUR DIOXIDE EMISSIONS TO THE LEVEL REQUIRED BY (MICHIGAN) RULE 336.1401 IS UNREASONABLY DISPROPORTIONATE TO THE BENEFITS WHICH WOULD BE OBTAINED THEREBY" (CONSUMERS POWER COMPANY APRIL 1983, P.8).

IN THIS CHAPTER, THE APPROACHES, PROCEDURES AND ASSUMPTIONS EMPLOYED BY CONSUMERS POWER COMPANY IN ESTIMATING THE COSTS AND BENEFITS OF COMPLYING WITH THE 1% SULPHUR IN FUEL REQUIREMENT WILL BE DISCUSSED AND

CRITIQUED. WITH CERTAIN QUALIFICATIONS, THE ESTIMATES PRESENTED BY THE COMPANY ARE REASONABLE AS FAR AS THEY GO. HOWEVER, IT IS ARGUED THAT OTHER TECHNOLOGIES OR CONTROL OPTIONS COULD HAVE BEEN EXAMINED THAT COULD ACHIEVE THE SULPHUR DIOXIDE OBJECTIVES AT LOWER COSTS THAN THOSE OPTIONS CONSIDERED BY CONSUMERS POWER. FURTHERMORE, THERE ARE A NUMBER OF ASSUMPTIONS ABOUT COSTS THAT HAVE BEEN MADE WHICH TEND TO YIELD ESTIMATES OF COSTS THAT ARE ON THE HIGH END OF THE POSSIBLE RANGE.

FINALLY, IT IS ARGUED THAT THERE ARE POTENTIAL BENEFITS FROM THE REDUCTION IN SO<sub>2</sub> EMISSIONS THAT HAVE NOT BEEN ADDRESSED IN THE CONSUMERS POWER SUBMISSION. TO THE EXTENT THAT THESE ADDITIONAL BENEFITS ARE VALUED BY INDIVIDUALS, AND BY SOCIETY AS A WHOLE, THE MONETARY VALUE OF THE BENEFITS HAS, THEREFORE, BEEN UNDERSTATED.

## 8.2 CRITIQUE OF COST ESTIMATES

ONLY TWO CONTROL TECHNOLOGIES OR OPTIONS WERE EXAMINED IN THE COST-BENEFIT ANALYSES FOR EACH PLANT. THESE WERE:

- LIMESTONE FLUE GAS DESULPHURIZATION (FGD);
- EASTERN LOW SULPHUR COAL (ELSC).

ACCORDING TO THE CONSUMERS POWER COMPANY DOCUMENTATION (APRIL 1983 AND AUGUST 1983), THE COMPANY'S PRODUCTION COST MODEL WAS USED TO DETERMINE THE ANNUAL COSTS OF FUEL, PURCHASED POWER AND OPERATION AND MAINTENANCE (O&M) REQUIRED TO OPERATE EACH POWER PLANT AS PROPOSED IN THE

COMPANY'S REQUEST. THE COMPANY'S PROPOSAL WAS DEFINED AS THE "BASE CASE". THEN THE EXTRA CAPITAL COSTS, FUEL, PURCHASED POWER, O&M AND OTHER ADVERSE CONSEQUENCES (TO THE COMPANY) OF EACH OF THE TWO EMISSION CONTROL OPTIONS THAT WOULD MEET THE SO<sub>2</sub> EMISSION OBJECTIVES WERE ESTIMATED AND COMPARED WITH THE "BASE CASE". CAPITAL COSTS WERE ANNUALIZED BY MULTIPLYING THE CAPITAL COST BY AN APPROPRIATE FIXED CHARGE RATE WHICH INCLUDES A MINIMUM ACCEPTABLE RETURN (PROFIT RATE), DEPRECIATION RATE, TAXES AND INSURANCE.

EXTRA AVERAGE ANNUAL O&M COSTS ASSOCIATED WITH THE NEW EQUIPMENT WERE ALSO ADDED TO THE ANNUALIZED CAPITAL COST ESTIMATE TO OBTAIN AN ESTIMATE OF THE EXTRA COSTS FOR A "TYPICAL" YEAR OF OPERATION. THE EXTRA COST OF THE LOW SULPHUR COAL OPTION WAS DUE TO THE HIGHER PRICE OF THE LOW SULPHUR COAL. BASED ON THE SUBMISSIONS FROM CONSUMERS POWER, THE EXTRA COSTS OF EACH OPTION ARE SUMMARIZED FOR EACH PLANT IN TABLE 8.1.

THERE WERE INSUFFICIENT DATA AND INFORMATION IN THE COMPANY'S DOCUMENTATION ABOUT EACH POWER PLANT AND ABOUT CERTAIN CRITICAL PARAMETERS, SUCH AS THE PRICE PER TON OF COAL, TO PERMIT DUPLICATION AND VERIFICATION OF THE ACTUAL COST ESTIMATES FOUND IN THE SUBMISSIONS. STAFF AT THE MICHIGAN PUBLIC SERVICE COMMISSION (OCTOBER 21, 1983) PREPARED AN INDEPENDENT ASSESSMENT OF THE COSTS OF THE TWO TECHNOLOGIES FOR EACH PLANT. HOWEVER, ACCORDING TO THE PRINCIPAL INVESTIGATOR OF THIS ANALYSIS, ADDITIONAL

SUBMISSIONS FROM THE COMPANY, AS WELL AS MEETINGS WITH COMPANY OFFICIALS, WERE REQUIRED TO OBTAIN SUFFICIENT INFORMATION TO DO THIS.

FOR EXAMPLE, THE COMPANY DOES NOT CLEARLY SPECIFY HOW MUCH EXTRA LOW SULPHUR COAL IT WOULD HAVE TO BURN AT EACH PLANT TO ACHIEVE THE 1% ANNUAL AVERAGE NOR DOES IT CLEARLY PROVIDE THE EXTRA COST OF THE LOWER SULPHUR COAL, OVER AND ABOVE THE COST OF THE COAL THAT THE COMPANY PROPOSES TO USE. THE COMPANY SUBMISSIONS ALSO DO NOT REVEAL THEIR BASES FOR ESTIMATING THE COST OF LOW SULPHUR COAL ALTERNATIVES.

A KEY [REDACTED]  
[REDACTED] TWO  
METHODS OF [REDACTED] THE  
[REDACTED] AIR POLLUTION CONTROL [REDACTED] ARE, IN  
FACT [REDACTED] WHICH  
COULD [REDACTED] SO<sub>2</sub> EMISSIONS.

FOR EXAMPLE, DETROIT [REDACTED]  
[REDACTED] FOR ACHIEVING THE 1% SULPHUR LIMIT AT  
ITS MONROE PLANT. CONSUMERS POWER HAS NOT DONE THIS.  
ANOTHER APPROACH INVOLVES [REDACTED]

ACCORDING TO THE DATA IN TABLE 2.2, TWO OTHER POWER  
PLANTS OWNED BY CONSUMERS POWER COMPANY, THE D.E. KARN  
AND THE J.C. WEADOCK PLANTS, HAVE A COMBINED CAPACITY OF

2,402,000 MW, ALMOST 500 MORE MW THAN THE COBB AND CAMPBELL PLANTS. BOTH THE WEADOCK AND KARN PLANTS ALREADY USE LOW SULPHUR COAL (ABOUT 0.85% SULPHUR). HOWEVER, KARN WAS OPERATED AT ONLY 18% CAPACITY DURING 1982 WHILE WEADOCK WAS ON LINE 28% OF THE TIME. COULD NOT MORE POWER BE GENERATED FROM THESE PLANTS IN ORDER TO ACHIEVE EMISSIONS AT COBB AND CAMPBELL THAT ARE EQUIVALENT TO THE 1% SULPHUR IN FUEL?

OF THE TWO SYSTEMS EXAMINED BY CONSUMERS POWER, WE AGREE THAT THE ~~LOW SULPHUR COAL OPTION IS LESS COSTLY THAN THE~~

~~FOR THE COMPANY~~  
~~90-111-1118~~ HOWEVER, THERE ARE A VARIETY OF OTHER FGD TECHNOLOGIES THAT ARE ACTUALLY BEING USED WHICH COULD BE SUBSTANTIALLY LESS COSTLY THAN THE LIMESTONE THROWAWAY SYSTEM EXAMINED BY CONSUMERS POWER. THERE ARE ALSO PROCESSES THAT RECOVER SALEABLE BY-PRODUCTS SUCH AS SULPHURIC ACID OR GYPSUM. MOREOVER, SULPHUR DIOXIDE GASES CAN BE USED DIRECTLY AS INPUTS TO SOME FERTILIZER PRODUCTION PROCESSES. THESE SYSTEMS INCLUDE THE CHIYODA T-121, DRY FGD WITH LIME, SULPHURIC ACID PRODUCTION, ETC.

GIVEN THE FIVE YEAR TIME FRAME, LOW SULPHUR COAL APPEARS TO BE THE LOWEST COST OF THE TWO OPTIONS TO ACHIEVE THE 1% SULPHUR EQUIVALENT EMISSIONS. HOWEVER, THERE ARE CERTAIN ADVANTAGES TO THE INSTALLATION OF AN FGD SYSTEM WHICH COULD BENEFIT THE COMPANY IN THE LONGER TERM. FIRST, ~~AN FGD SYSTEM WOULD PERMIT THE COMPANY TO USE MUCH~~  
~~MORE ABUNDANT~~ (HENCE, CHEAPER) ~~LOW SULPHUR COAL~~ (E.G.

UP TO 5.0% SULPHUR COAL) ~~AND STILL ACHIEVE THE 1% SULPHUR EMISSIONS GOVERNMENT REQUIREMENT.~~ THIS COULD PROVIDE THE COMPANY GREATER FLEXIBILITY IN ITS USE OF FUELS AS WELL AS REDUCE ITS ANNUAL COAL PURCHASE COSTS. ANOTHER POTENTIAL ADVANTAGE OF SOME FGD SYSTEMS ~~IS THAT THEY CAN BE INSTALLED IN A SHORT PERIOD OF TIME.~~

THERE ARE A NUMBER OF ASSUMPTIONS AND ASSERTIONS MADE BY CONSUMERS POWER WHICH TEND TO PRODUCE HIGH ESTIMATES OF THE FGD SYSTEM COSTS. FOR EXAMPLE:

- THE FGD SYSTEM SPECIFIED FOR CAMPBELL UNITS 1 AND 2 CONSISTS OF FOUR FGD MODULES EACH OF WHICH WOULD HANDLE 1,000,000 ACTM OF FLUE GAS. THIS IS MORE THAN TWICE THE FLUE GAS ACTUALLY GENERATED BY THE TWO BOILER UNITS. THIS MUCH OVER-CAPACITY WOULD NOT BE REQUIRED FOR THE RELIABLE OPERATION OF AN FGD SYSTEM.
- PRESENT FGD SYSTEMS OPERATE NEAR STOICHIOMETRY SO THAT THE 30-35% EXTRA LIMESTONE ESTIMATED TO BE REQUIRED WOULD LIKELY NOT BE NEEDED. CONSEQUENTLY, THE 4,000 ACRE FEET OF SLUDGE DISPOSAL AREA THAT IS SAID TO BE REQUIRED FOR THE CAMPBELL PLANT APPEARS TO BE SUBSTANTIALLY OVER-ESTIMATED.
- FGD MODULES COULD BE INSTALLED IN CONSIDERABLY LESS THAN SIX WEEKS AND POWER PLANT DOWN TIME WOULD THUS BE PROPORTIONATELY REDUCED.

- ONLY PARTIAL SCRUBBING OF FLUE GASES FROM THE TWO PLANTS WOULD BE NECESSARY TO MEET THE 1% SULPHUR REQUIREMENTS. THIS COULD SUBSTANTIALLY REDUCE THE CAPITAL AND OPERATING COSTS.

IN SUMMARY, WE CAN ONLY CONCLUDE THAT THE COMPANY HAS NOT MADE A SERIOUS EFFORT TO FIND THE MOST EFFICIENT AND LOWEST COST (OR PROFIT MAXIMIZING) METHOD OF COMPLYING WITH THE LEGISLATED SO<sub>2</sub> EMISSION OBJECTIVES. DENYING THIS APPLICATION WOULD PROVIDE THE COMPANY WITH AN ADDED INCENTIVE TO LOOK FOR, AND HOPEFULLY IMPLEMENT, LOWER COST METHODS OF ACHIEVING THE SO<sub>2</sub> OBJECTIVE.

FURTHERMORE, BECAUSE OF THE FOREGOING QUESTIONS THAT HAVE BEEN RAISED ABOUT THE COST ESTIMATES AND THEIR BASES, IT IS NOT CLEAR AT THIS STAGE JUST HOW MUCH MORE, OVER AND ABOVE THE BASE CASE, IT WOULD ACTUALLY COST THE COMPANY TO COMPLY WITH RULE 336.1401(4). IF A REDUCTION IN SO<sub>2</sub> EMISSIONS IN CONFORMANCE TO THE 1% SULPHUR IN FUEL REQUIREMENT WILL INCREASE COSTS TO THE COMPANY BY \$17 M OR \$18 M PER YEAR, THE MICHIGAN PUBLIC SERVICE COMMISSION ESTIMATED THAT THIS WOULD INCREASE THE MONTHLY RESIDENTIAL ELECTRIC BILL BY ONLY 1% (MICHIGAN PUBLIC SERVICE COMMISSION, OCTOBER 21, 1983). AGAIN, IF THE COMPANY WILL BE ALLOWED TO PASS MOST, IF NOT ALL, OF THESE COST INCREASES ON TO ITS CUSTOMERS (SO AS TO MAINTAIN THE COMPANY'S AUTHORIZED RATE OF RETURN OR PROFIT), IT WOULD BE PRUDENT TO INVESTIGATE WHETHER THE BENEFITS THAT RESULT FROM THESE ACTIONS ARE VALUED SUFFICIENTLY BY ELECTRICITY CUSTOMERS AND BY SOCIETY AS

A WHOLE, TO JUSTIFY THESE EXTRA EXPENSES. WE BELIEVE THAT THIS PARTICULAR QUESTION HAS ALSO BEEN INADEQUATELY ADDRESSED BY CONSUMERS POWER.

### 8.3 CRITIQUE OF BENEFITS ASSESSMENT

THE APPROACH THAT WAS USED FOR BENEFITS ESTIMATION BY CONSUMERS POWER COMPANY IS CRUDE AND IS LIKELY TO BE INACCURATE. WE BELIEVE THAT THERE ARE BETTER APPROACHES THAT CAN BE USED TO MEASURE AND DISPLAY THE PUBLIC BENEFITS (BENEFITS TO SOCIETY AND TO INDIVIDUALS NOT CONNECTED WITH THE POLLUTER) OF POLLUTION CONTROL. IN THIS SECTION, THE APPROACH THAT WAS USED BY CONSUMERS POWER IS DESCRIBED AND ITS WEAKNESSES NOTED. AN ALTERNATIVE APPROACH IS THEN SUGGESTED.

THE APPROACH OR "METHODOLOGY" IS DESCRIBED IN A REPORT BY COHEN (1977) FOR THE AIR POLLUTION CONTROL BOARD. THIS STUDY WAS CRITIQUED BY GREENFIELD AND PEYTON (1978) IN A REPORT COMMISSIONED BY CONSUMERS POWER. THE COHEN REPORT IDENTIFIES REDUCTIONS IN MORTALITY, MORBIDITY AND MATERIALS DAMAGES AS THE KEY PUBLIC BENEFITS TO BE ACHIEVED BY REDUCTIONS IN AMBIENT AIR QUALITY. COEFFICIENTS WERE DEVELOPED BY ESTIMATING THE TOTAL MONETARY VALUE OF ALL THE EFFECTS ATTRIBUTABLE TO AMBIENT SULPHUR DIOXIDE CONCENTRATIONS FOR A GIVEN YEAR IN A SPECIFIC REGION. THIS VALUE IS THEN DIVIDED BY THE POPULATION OF THE GIVEN REGION AND BY THE AVERAGE SO<sub>2</sub> CONCENTRATION TO GET A \$ PER PERSON PER UG SO<sub>2</sub> PER YEAR COEFFICIENT.

AS SHOWN IN TABLE 8.2, COHEN REPORTS THAT, IN 1974, A COEFFICIENT FOR THE SUM OF MORTALITY, MORBIDITY AND MATERIALS DAMAGES WAS  $\$1.84/\text{UG}/\text{SO}_2/\text{M}^3/\text{PERSON}/\text{YEAR}$ .

THE BENEFIT OF A REDUCTION IN  $\text{SO}_2$  CONCENTRATIONS IN AN AREA IS DETERMINED BY MULTIPLYING THE COEFFICIENT BY THE NUMBER OF PEOPLE EXPOSED AND THEN BY THE DECREASE IN  $\text{SO}_2$  CONCENTRATION IN  $\text{UG SO}_2$ . THIS APPROACH MAKES TWO IMPLICIT AND QUESTIONABLE ASSUMPTIONS.

FIRST, A STATIC COEFFICIENT, WHICH WAS CALCULATED BY USING DATA ON THE EFFECTS AT A SINGLE CONCENTRATION LEVEL, IS APPLIED TO A DYNAMIC ESTIMATE OF THE CHANGE IN AMBIENT CONCENTRATION.

SECOND, THE APPROACH ASSUMES THAT THE CHANGE IN VALUE OR BENEFIT IS INVARIANT AT ANY LEVEL OF POLLUTION. IN OTHER WORDS, A  $10 \text{ UG SO}_2/\text{M}^3$  SHIFT BETWEEN 10 AND  $20 \text{ UG SO}_2/\text{M}^3$  HAS THE SAME VALUE AS A  $10 \text{ UG SO}_2/\text{M}^3$  SHIFT BETWEEN 1,000 AND  $1,010 \text{ UG SO}_2/\text{M}^3$ . THIS MAY NOT BE THE CASE.

GREENFIELD AND PEYTON (1978) ARGUE THAT THERE IS NO EVIDENCE THAT THERE ARE HEALTH EFFECTS AT AMBIENT CONCENTRATIONS BELOW NATIONAL  $\text{SO}_2$  STANDARDS. CONSEQUENTLY, AS LONG AS THE AMBIENT AIR QUALITY LEVELS AFFECTED BY THE POWER PLANTS IN QUESTION REMAIN BELOW THESE STANDARDS, THERE WILL BE NO REDUCTIONS IN HEALTH EFFECTS, HENCE NO BENEFITS IN TERMS OF MORTALITY AND MORBIDITY.

WHILE GREENFIELD AND PEYTON AGREE THAT MATERIALS DAMAGE MAY BE OCCURRING AT CURRENT CONCENTRATIONS, THEY ARGUE THAT COHEN'S COEFFICIENT OVERSTATES THE VALUE OF THESE EFFECTS. COHEN SUGGESTS A COEFFICIENT OF  $\$0.824/\text{UG}/\text{M}^3/\text{PERSON}/\text{YEAR}$  FOR MATERIALS DAMAGES ALONE (SEE TABLE 8.2) WHILE GREENFIELD AND PEYTON CONCLUDE THAT AT "BETWEEN 20 AND 80  $\text{UG}/\text{SO}_2/\text{M}^3$ ", THE CHANGE IN THE ANNUAL PER CAPITA DAMAGE OF  $\text{SO}_2$  TO ALL MATERIAL IS ESTIMATED TO RANGE FROM  $\$0.34$  AND  $\$0.50$  (1977 DOLLARS) PER (CHANGE IN)  $\text{UG}/\text{SO}_2/\text{M}^3$ ". CONSUMERS POWER, THEREFORE, USED A COEFFICIENT OF  $\$0.44/\text{UG}/\text{SO}_2/\text{M}^3/\text{PERSON}/\text{YEAR}$  IN LOCATIONS WHERE MEAN ANNUAL  $\text{SO}_2$  CONCENTRATIONS ARE ABOVE 20  $\text{UG}/\text{M}^3$ . FOR COMPARATIVE PURPOSES, CONSUMERS POWER PRODUCES ESTIMATES APPLYING THE COHEN COEFFICIENT FOR MATERIALS AND HEALTH DAMAGES ( $\$1.84/\text{UG}/\text{M}^3/\text{PERSON}/\text{YEAR}$ ) AS WELL AS THE GREENFIELD COEFFICIENT FOR MATERIALS ( $\$0.44/\text{UG}/\text{SO}_4/\text{M}^3/\text{PERSON}/\text{YEAR}$ ) AT EACH PLANT.

UNFORTUNATELY, CONSUMERS POWER DOES NOT EXPLAIN FULLY HOW ITS ESTIMATES WERE ACTUALLY CALCULATED. BECAUSE THE COEFFICIENTS WERE IN 1974 OR 1977 DOLLARS, THE VALUES MAY HAVE BEEN ESCALATED TO 1983 DOLLARS AS WAS DONE BY DETROIT EDISON (1981). DETROIT EDISON'S PROCEDURE IS EXPLAINED IN THE PROVINCE OF ONTARIO (JUNE 30, 1982, PP. 103 AND 104) BRIEF TO THE MICHIGAN AIR POLLUTION CONTROL COMMISSION.

USING THE COHEN COEFFICIENT,  $\$1.84/\text{UG}/\text{SO}_2/\text{M}^3/\text{PERSON}/\text{YEAR}$ , CONSUMERS POWER CO. ESTIMATED THAT ACHIEVING THE 1% IN SULPHUR LEVEL OF EMISSIONS WILL YIELD ANNUAL BENEFITS, IN

TERMS OF REDUCED MORTALITY, MORBIDITY AND MATERIALS DAMAGES, THAT ARE VALUED AT \$2 MILLION FOR THE COBB PLANT AND \$4 MILLION FOR THE CAMPBELL PLANT. THE COMPANY THEN APPLIED GREENFIELD'S COEFFICIENT FOR MATERIALS DAMAGE ( $\$0.44/\text{UG SO}_2/\text{M}^3/\text{PERSON}/\text{YEAR}$ ) WHICH YIELDED AN ESTIMATE OF ONLY \$0.1 MILLION PER YEAR AT COBB AND \$0.2 MILLION AT CAMPBELL. AS NOTED, CONSUMERS POWER DID NOT EXPLAIN EXACTLY HOW THESE VALUES WERE CALCULATED. FOR EXAMPLE, WERE THESE ESTIMATES ADJUSTED FOR INFLATION AND WERE THEY "PRESENT WORTHED" (E.G. PRESENT VALUE OF FUTURE BENEFITS CALCULATED)? MOREOVER, WHAT DISCOUNT AND/OR INFLATION RATES WERE USED?

AT ANY RATE, COMPARING THESE ESTIMATES WITH THE ESTIMATED ANNUAL COSTS (OVER FIVE YEARS) OF FGD OR LOW SULPHUR COAL (SEE TABLE 8.1), CONSUMERS POWER ARGUES THAT COSTS ARE UNREASONABLY DISPROPORTIONATE TO THE BENEFITS.

THE BENEFIT ESTIMATES PROVIDED BY CONSUMERS POWER LIKELY UNDERSTATE BENEFITS OF  $\text{SO}_2$  EMISSION REDUCTIONS AT THE TWO PLANTS FOR SEVERAL REASONS. FIRST, THE BENEFITS ASSOCIATED WITH REDUCED ACID RAIN AND SOOTY DEPOSITION ARE CONSIDERED. NO ATTEMPT IS MADE TO QUANTIFY THESE BENEFITS WHICH WOULD BE SIGNIFICANT. SECOND, THE BENEFITS OF REDUCED DRY DEPOSITION TO AGRICULTURE, FORESTS AND HUMAN SYSTEMS.

IN ADDITION, THE BENEFITS OF REDUCED ACID RAIN, WHICH GOVERNMENT AND INDUSTRY HAVE BOTH ADOPTED, ARE NOT INCLUDED IN THE ESTIMATES OF THE ENVIRONMENT SUCH AS THE BENEFITS TO AGRICULTURE, FORESTS AND HUMAN SYSTEMS.

~~ARTIFACTS AND THE PRESERVATION OF CLEAN AIR AND WATER FOR~~  
~~FUTURE GENERATIONS~~ MANY PEOPLE ALSO ARE WILLING TO PAY  
SOMETHING TO PRESERVE RESOURCES FOR THEIR OWN FUTURE USE  
OR TO PRESERVE THEM FOR THEIR OWN SAKE.

WHILE THESE VALUES ARE NOT REVEALED IN PRIVATE MARKET  
TRANSACTIONS, QUESTIONNAIRES AND SURVEY PROCEDURES,  
CALLED CONTINGENCY VALUATION SURVEYS, HAVE BEEN DEVELOPED  
THAT YIELD RELIABLE AND ACCURATE ESTIMATIONS OF THE  
AMOUNTS PEOPLE ARE WILLING TO PAY TO GAIN A CLEANER  
ENVIRONMENT OR, ALTERNATIVELY, WHAT THEY WOULD REQUIRE IN  
MONETARY COMPENSATION TO ENDURE A DECLINE IN  
ENVIRONMENTAL QUALITY. A CRITICAL REVIEW OF THE SURVEY  
METHODOLOGY CAN BE FOUND IN THE 1981 REPORT BY MYRA  
SCHIFF CONSULTANTS LTD.

THE VALUATIONS GENERATED BY THESE SURVEYS ARE  
COLLECTIVELY CALLED AMENITY VALUES AND THEY CAN BE ADDED  
TO THE ESTIMATES OF THE MONETARY VALUES OF REDUCED  
BIOPHYSICAL EFFECTS ON CROPS, FORESTS, BUILDINGS OR OTHER  
MARKETABLE GOODS AND SERVICES. THE AMENITY VALUES  
ASSOCIATED WITH REDUCING THE EMISSIONS FROM THE CONSUMERS  
POWER PLANTS HAVE BEEN IGNORED IN THE CONSUMERS POWER  
SUBMISSIONS AND, BY IMPLICATION, ARE ASSUMED TO BE ZERO  
IN THE COST-BENEFIT ANALYSES.

A THIRD FACTOR CONCERNS THE OMISSION OF MORTALITY AND  
MORBIDITY BENEFITS BECAUSE THE AMBIENT AIR QUALITY  
CONCENTRATIONS ARE ALREADY BELOW LEVELS WHICH ARE  
INTENDED TO PROTECT HUMAN HEALTH. THE USE OF THRESHOLDS

IS A CONTROVERSIAL ISSUE AND SHOULD BE CAREFULLY QUALIFIED. FOR EXAMPLE, THE AMERICAN LUNG ASSOCIATION OF MICHIGAN AND DR. HOMER BOUSHEY (1981) HAVE SHOWN THAT ASTHMATICS AND CERTAIN OTHER INDIVIDUALS IN THE EXPOSED POPULATION MAY SUFFER HEALTH EFFECTS AT RELATIVELY LOW CONCENTRATIONS OF POLLUTANTS. WHILE THESE SENSITIVE INDIVIDUALS MAY REPRESENT A SMALL PART OF THE TOTAL POPULATION, ONE CANNOT SAY WITH CERTAINTY THAT THERE ARE NO HEALTH BENEFITS AT CONCENTRATIONS BELOW NATIONAL AMBIENT AIR QUALITY STANDARDS.

A FOURTH CONSIDERATION THAT COULD LEAD TO A HIGHER ESTIMATE OF THE VALUE OF THE BENEFITS OF REDUCING SO<sub>2</sub> EMISSIONS, IS THE FACT THAT THE COMPANY ONLY CITES BENEFITS FOR THE YEARS 1985-1990, THE PERIOD OF THE REQUESTED CONSENT ORDER. THESE BENEFITS, AND ANY OTHERS THAT SUBSEQUENTLY MAY BE DISCOVERED, WILL ACCRUE AS LONG AS THE PLANT IS IN OPERATION. THIS MEANS THAT THE BENEFITS DURING FUTURE YEARS SHOULD ALSO BE DETERMINED AND COMPARED WITH THE RELEVANT COSTS. MOREOVER, THE REAL VALUE (ADJUSTED FOR INFLATION) OF THESE BENEFITS MAY INCREASE IN THE FUTURE AS OTHER SOCIO-ECONOMIC FACTORS AND CHARACTERISTICS CHANGE.

BECAUSE OF UNCERTAINTY ABOUT THE VARIOUS FACTORS AND ASSUMPTIONS THAT ARE EMPLOYED IN THESE ESTIMATES, SINGLE-VALUED ESTIMATES LIKE THOSE THAT HAVE BEEN PRESENTED TELL US VERY LITTLE. RANGES OF ESTIMATES INDICATING WHICH FACTORS OR ASSUMPTIONS THAT CAN BE CHANGED PROVIDE BETTER COMPARATIVE INFORMATION.

CONSEQUENTLY, IN ORDER TO MAKE A TRULY COMPREHENSIVE ASSESSMENT OF THE BENEFITS OF ABATEMENT, ALL OF THE BIOPHYSICAL EFFECTS OF REDUCTIONS IN AMBIENT AIR CONCENTRATIONS AND ACIDIC DEPOSITION SHOULD BE DETERMINED, INCLUDING CHANGES IN INTANGIBLE QUALITIES AND FEATURES.

A MORE COMPREHENSIVE BENEFIT ESTIMATION PROCEDURE WOULD, THEREFORE, INCLUDE THE FOLLOWING STEPS:

1. IDENTIFICATION OF THE VARIOUS BIOPHYSICAL DAMAGE AND EFFECTS CATEGORIES, INCLUDING AMENITY EFFECTS;
2. DETERMINATION OF RELEVANT BIOPHYSICAL DOSE-RESPONSE RELATIONSHIPS;
3. ENUMERATION OF THE VARIOUS POPULATIONS THAT ARE AT RISK, INCLUDING PEOPLE, NATURAL RESOURCES AND MAN-MADE ARTIFACTS;
4. QUANTITATIVE ESTIMATION OF THE BIOPHYSICAL EFFECTS OR CHANGES THAT OCCUR (E.G. REDUCTIONS IN CROP PRODUCTION, REDUCED DAMAGES OR INCREASED MAINTENANCE FOR BUILDINGS, REDUCED MORTALITY AND MORBIDITY, ETC.);
5. VALUATION (IN MONETARY UNITS) OR WEIGHTING BY SOME OTHER EXPLICIT PROCEDURE OF THESE BIOPHYSICAL EFFECTS OR CHANGES; AND

6. QUANTITATIVE ESTIMATION OF THE AMENITY VALUES ASSOCIATED WITH THE CHANGES BY MEANS OF CONTINGENT VALUE SURVEYS.

IT IS SUGGESTED THAT MORE EXPLICIT AND QUANTITATIVE INFORMATION ABOUT THE VARIOUS BIOPHYSICAL EFFECTS THAT ARE NOTED IN TABLE 8.3 WOULD BE USEFUL FOR FUTURE MICHIGAN AIR POLLUTION CONTROL COMMISSION DELIBERATIONS. PRESENTING ONLY DOLLAR VALUE ESTIMATES OF THE BENEFITS TENDS TO HIDE INFORMATION ABOUT THE QUALITATIVE NATURE OF THESE EFFECTS. IT IS RECOGNIZED THAT A DEARTH OF VERIFIED BIOPHYSICAL DOSE-RESPONSE RELATIONSHIPS FOR MANY OF THE POLLUTANT-RECEPTOR CATEGORIES IS AN IMPORTANT IMPEDIMENT TO THESE TYPES OF ESTIMATES.

FURTHERMORE, A DISPLAY OF THE POPULATIONS AND RESOURCES AT RISK FROM THE POLLUTION DAMAGES WOULD HELP CLARIFY THE EXTENT OF ANY EFFECTS.

ONCE THE BIOPHYSICAL AND AMENITY EFFECTS ARE IDENTIFIED AND ENUMERATED TO THE EXTENT POSSIBLE, THEN THE PROBLEM OF WEIGHTING THESE EFFECTS CAN BE ADDRESSED. MONETARY VALUATION IS ONE METHOD OF ASSIGNING WEIGHTS TO VARIOUS INCOMMENSURATE QUANTITIES. MARKET PRICES, WHERE AVAILABLE, PROVIDE WIDELY ACCEPTED MONETARY VALUATIONS THAT CAN BE USED IN COST-BENEFIT ANALYSES.

THERE ARE A NUMBER OF METHODOLOGIES THAT HAVE BEEN DEVELOPED FOR ESTIMATING THE MONETARY VALUES OF DIFFERENT BIOPHYSICAL AND AMENITY CONSEQUENCES OF ENVIRONMENTAL

PROTECTION EFFORTS. WHERE BIOPHYSICAL EFFECTS REDUCE OR INCREASE OUTPUTS OF MARKETABLE PRODUCTS OR WHERE THEY AFFECT THE COSTS OF PRODUCING GIVEN LEVELS OF PRODUCTS, SUCH AS FROM CROPS OR BUILDING MAINTENANCE, THE MONETARY VALUES OF THESE EFFECTS CAN BE ESTIMATED FROM MARKET PRICES.

WHERE BIOPHYSICAL EFFECTS DO NOT HAVE MARKET PRICES ASSOCIATED WITH THEM OR THERE ARE AMENITY FEATURES, OTHER METHODS HAVE BEEN DEVELOPED TO ESTIMATE THE WILLINGNESS TO PAY FOR DIFFERENT BENEFICIAL CONSEQUENCES.

FOR EXAMPLE, THE WELL-KNOWN "TRAVEL COST METHOD" TO ESTIMATE MONETARY VALUES OF CHANGES IN RECREATIONAL OPPORTUNITIES HAS OFTEN BEEN APPLIED. MOREOVER, THE CONTINGENT VALUE SURVEY METHOD IS BEING REFINED AND IMPLEMENTED IN AN INCREASING NUMBER OF CIRCUMSTANCES. MORE IMPORTANTLY, THERE IS EVIDENCE THAT THE RESULTS OF SUCH SURVEYS ARE ACTUALLY BEING USED IN DECISION-MAKING.

THE U.S. EPA IS FUNDING A SERIES OF STUDIES TO DEVELOP STANDARDIZED METHODS FOR BENEFITS MEASUREMENT. THIS RESEARCH EFFORT SHOULD HELP DEVELOP A MORE WIDELY UNDERSTOOD AND USEFUL SET OF METHODS FOR USE BY AGENCIES LIKE OUR OWN.

WHILE THE COST-BENEFIT ANALYSES PRESENTED BY CONSUMERS POWER HAVE PROVIDED ESTIMATES OF THE VALUE OF REDUCED MATERIALS DAMAGES, WE RESPECTFULLY SUGGEST THAT THESE ESTIMATES REPRESENT A MINIMUM VALUE OF THE BENEFITS OF

SO<sub>2</sub> REDUCTIONS. ONTARIO WILL CONTINUE TO SHARE INFORMATION AND INVITES THE COMMISSION TO WORK ON JOINT PROJECTS TO FURTHER QUANTIFY THE EXTENT OF THE BIOPHYSICAL AND HUMAN BENEFITS FLOWING FROM ENVIRONMENTAL PROTECTION ACTIVITIES FOR WHICH FUTURE GENERATIONS WILL BE THANKFULL.

TABLE 8.1

TOTAL EXTRA COSTS OF ACHIEVING SO<sub>2</sub> EMISSIONS THAT ARE  
EQUIVALENT TO 1% SULPHUR IN FUEL AT THE COBB AND  
CAMPBELL POWER PLANTS, MICHIGAN

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<u>Plant</u>	<u>Capital Cost</u>	<u>Annual O&amp;M</u>	<u>Total Extra Cost 1985-1989</u>
(millions 1985 dollars)			
Cobb (1)			
Low Sulphur Coal	-	-	41
FGD	174.6	16.8	308
Campbell Units 1 and 2 (2)			
Low Sulphur Coal	-	-	53
FGD	222.3	21.4	369

Sources: (1) Consumers Power Company (August 1983, Vol. I, P. 43,  
Vol. II, p. 7).

(2) Consumers Power Company (April 1983, Vol. I, p. 36),  
Addendum from Consumers Power Company October 1983.

TABLE 8.2

DAMAGE COEFFICIENTS FOR SO<sub>2</sub> AND PARTICULATES

(\$/ug/m<sup>3</sup>/person/year)

Receptor Category	<u>Particulates</u>	<u>Sulphur Dioxide</u>	
		<u>Literature Survey</u>	<u>Cohen, Fishelson and Gardner (1974)</u>
Human Health			
Mortality	\$0.294	\$0.394	\$0.294
Morbidity	\$0.721	\$0.100	\$0.721
Materials	<u>\$2.320</u>	<u>\$0.428</u>	<u>\$0.824</u>
Total	<u>\$3.330</u>	<u>\$0.922</u>	<u>\$1.840</u>

Source: Cohen (1977, pp. 14 and 21)

TABLE 8.3

POLLUTANTS FROM A POWER PLANT AND THE VARIOUS  
RECEPTOR CATEGORIES WHICH CAN BE AFFECTED

	<u>Pollutant Type</u>			
	<u>Ambient Air Quality</u>			<u>Acidic Deposition</u>
<u>Biophysical Receptor Effect/Category</u>	<u>SO<sub>2</sub></u>	<u>NO<sub>x</sub></u>	<u>Particulates</u>	
Human Health				
Mortality	Y	Y	Y	-
Morbidity	Y	Y	Y	-
Vegetation				
Agricultural Crops	Y	Y	Y	Y
Forests	Y	Y	Y	Y
Animals and Livestock	Y	Y	Y	-
Materials and Structures	Y	?	Y	Y
Water Quality and Aquatic Systems	Y	?	?	Y
Human Perceptions and Aesthetics	Y	-	Y	-

Code: Y = effect has been observed.

- = no known effect.

? = no information available.

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9. SUMMARY AND CONCLUSIONS

CONSUMERS POWER IS APPLYING FOR AN EXTENDED  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED] CAMPBELL POWER PLANTS  
[REDACTED] 1994

THIS ONE PERCENT SULPHUR IN FUEL RULE  
[REDACTED] 72.  
MOST SOURCES WITHIN THE STATE ARE IN COMPLIANCE WITH THIS  
[REDACTED]

IN SUMMARY, ONTARIO CONTENTS:

- THAT COMPLIANCE WITH THE STATE RULE COULD [REDACTED]  
[REDACTED] FROM THE [REDACTED] AND CAMPBELL PLANTS  
[REDACTED] THESE SO<sub>2</sub> EMISSIONS CONTRIBUTE TO  
THE OVERALL ATMOSPHERIC LOADING OF POLLUTANTS WHICH  
ARE SUBSEQUENTLY DEPOSITED ON SENSITIVE ECOSYSTEMS;
- THAT THE COMMISSION SHOULD CONSIDER THE ISSUES OF  
TRANSBOUNDARY AIRFLOWS AND THE RESULTANT ACIDIC  
DEPOSITION IN REACHING ITS DECISION. SINCE IT HAS  
BEEN ESTABLISHED THAT A NUMBER OF PRIMARY AND  
SECONDARY POLLUTANTS CAN UNDERGO LONG RANGE  
TRANSPORT, SULPHUR DIOXIDE EMISSIONS FROM THE COBB AND  
CAMPBELL PLANTS CANNOT BE CONSIDERED IN ISOLATION.  
THEY CONSTITUTE A SIGNIFICANT SOURCE OF POLLUTION IN  
NORTHEASTERN NORTH AMERICA WHICH, BEING THE PRECURSORS

TO ACID DEPOSITION, ARE A CAUSE OF ADVERSE EFFECTS TO SENSITIVE ECOSYSTEMS IN MICHIGAN AND OTHER JURISDICTIONS;

- THAT A NUMBER OF ~~ADVERSE AQUATIC EFFECTS~~, INCLUDING LAKE ACIDIFICATION, LOSSES OF FISH POPULATIONS AND REDUCED RECREATIONAL ENJOYMENT MAY BE OCCURRING IN SENSITIVE ECOSYSTEMS IN MICHIGAN AND ONTARIO AS A RESULT OF ACIDIC DEPOSITION;
- THAT INCREASING EMISSIONS OF THE PRECURSOR POLLUTANTS TO ACIDIC DEPOSITION CAN ONLY ~~INCREASE THE~~ POTENTIAL FOR ~~DAMAGE TO~~ SOILS, FORESTS AND AGRICULTURE;
- THAT THE COMPANY DID ~~NOT CONSIDER~~ THROUGH REVIEW ~~THE~~ TECHNOLOGIES AND METHODS WHICH ~~COULD BE EMPLOYED TO ENSURE COMPLIANCE~~ (FOR EXAMPLE, COAL BLENDING AND LEAST-EMISSIONS DISPATCHING WERE NOT CONSIDERED);
- THAT THE ~~COST-BENEFIT ANALYSES PRESENTED~~ BY CONSUMERS POWER SHOW THE MINIMUM VALUE OF REDUCED MATERIALS DAMAGE, ~~THEY~~ ASCRIBE A ZERO VALUE TO VISIBILITY, AESTHETICS, HISTORICAL AND ARCHEOLOGICAL ARTIFACTS AND THE PRESERVATION OF CLEAN AIR AND WATER FOR FUTURE GENERATIONS AND DO NOT ACCOUNT FOR POSSIBLE HEALTH EFFECTS ON SENSITIVE INDIVIDUALS WITHIN THE POPULATION;

- THAT GRANTING THE COMPANY'S APPLICATIONS WOULD BE IN  
~~VIOLATION OF THE SPIRIT OF THE MEMORANDUM OF UNDERSTANDING~~  
TRANSBOUNDARY AIR POLLUTION SIGNED BY CANADA AND THE  
UNITED STATES IN AUGUST 1980.

SINCE A FIRM STANCE WAS TAKEN WITH RESPECT TO A SIMILAR APPLICATION FROM DETROIT EDISON FOR ITS MONROE POWER PLANT, ONTARIO, THEREFORE, RECOMMENDS DENIAL OF THE CONSUMERS POWER COMPANY REQUESTS FOR AN EXTENSION OF THE COMPLIANCE DATE WITH THE MICHIGAN ONE PERCENT OR EQUIVALENT SULPHUR IN FUEL RULE FOR ITS COBB AND CAMPBELL POWER PLANTS.

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**.A17**  
**P74**  
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Presentation to : the Michigan  
air pollution control commission  
in opposition to the Consumers  
Power Company to delay

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